DOCUMENT RESUME

ED 175 095 EA 011 938

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TITLE Campus Energy Management Projects.
INSTITUTION National Association of Coll. and Univ. Business Officers, Washington, D.C.
SPONS AGENCY Department of Health, Education, and Welfare, Washington, D.C.; EXXON Corp., New York, N.Y.
PUB DATE 79
CONTRACT 300-78-0173
NOTE 60p.
AVAILABLE FROM National Association of College and University Business Officers, One Dupont Circle, Suite 510, Washington, D.C. 20036 ($7.50)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Architectural Elements; Building Improvement; Building Operation; *Cost Effectiveness; Electrical Systems; *Energy Conservation; *Facility Guidelines; Heating; Heat Recovery; Higher Education; Lighting; Mechanical Equipment; *Performance Specifications; *Projects; Utilities; Ventilation

ABSTRACT

This publication is a compilation of data concerning energy conservation measures at more than 60 colleges and universities in the United States and Canada. The data are presented for the information of all who are interested in the variety of ways in which institutions of higher education are managing energy. Project descriptions are divided into two sections, "Projects in Detail" and "Projects in Brief." The sections are subdivided into such categories as "Building Envelope"; "Electrical Systems"; "Heating, Ventilation, and Air Conditioning (HVAC) Systems"; "Building Operations"; and "Utilities Production, Distribution." An "Index of Institutions" is provided for those who wish to obtain additional information about the projects. Data appearing in this publication were supplied by the institutions whose projects are presented. Readers are cautioned that correct installation is essential for proper performance of any system, machinery, or component parts. (Author/MLF)

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Printed in the United States of America

Edited and designed by Lanora Welzenbach

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Preface

Campus Energy Management Projects is a compilation of data concerning energy conservation measures at more than sixty colleges and universities in the United States and Canada. These data are presented for the information of all who are interested in the variety of ways in which institutions of higher education are managing energy.

This publication is a project of the Energy Task Force (see p. 58 for list of current members), which was established in March 1975 to encourage and stimuate effective energy management programs at colleges and universities. The Energy Task Force is a joint effort of the American Council on Education, the Association of Physical Plant Administrators of Universities and Colleges, and the National Association of College and University Business Officers (NACUBO). The generous funding of the Exxon Corporation, which supports the overall program of the Energy Task Force, has helped make possible the publication of *Campus Energy Management Projects.* Further, the booklet was prepared in part under contract number 300-78-0173 with the U.S. Department of Health, Education, and Welfare, Office of Education, Energy and Education Action Center, through NACUBO.

Project descriptions in this publication are divided into two sections, "Projects in Detail" and "Projects in Brief"; these titles are self-explanatory. The sections are subdivided into such categories as "Building Envelope," "Electrical Systems," "HVAC Systems," etc. An "Index of Institutions" is provided for those who wish to obtain additional information about the projects. Data appearing in this publication were supplied by the institutions whose projects are presented; neither NACUBO nor the Energy Task Force has attempted to verify their accuracy. Further, readers are cautioned that correct installation is essential for proper performance of any system, machinery, or component parts.

The process of selecting energy management projects for publication was developed by Lonnan Council, a member of the Energy Task Force and Director of Physical Plant, Texas A&M University. It was not possible to use all of the large number of project reports submitted for publication, but the enthusiastic response to the request for information was very gratifying. Of the projects finally selected for publication, some are representative of energy conservation measures employed by many institutions and some are unusual or unique. It is hoped that this compilation will prove to be a worthwhile contribution to the literature on energy management.

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Projects in Detail

University of Louisville
Louisville, KY
Enrollment: 16,300

Installation of Solar Reflective Film

In April 1976, solar reflective film was installed on an area of glass 122 feet long and 10 feet high. This single-pane window wall of the cataloging department, Main Library, has eastern exposure and the building design did not allow for sufficient heating and cooling, which caused significant discomfort to occupants both in winter and summer.

Project Justification

Venetian blinds were installed, but they did not help the situation because the area also suffered from marginal lighting intensity and the blinds added to this problem. Installation of solar film would not require additional lighting, since the university's energy conservation program requires a level of 50 to 60 foot-candles and, with the use of the solar film on the window wall, it was possible to maintain a 60 foot-candle level of illumination at desk height.

Installation Details

The film used by the university is Solar-X PS-80, manufactured by the Solar Control Products Corporation, Newton, Massachusetts, and is available in several styles (for example, silver and bronze). The university chose silver, which produced a high-quality, mirror-like appearance on the exterior.

The film was installed by two members of the university painting crew who had had experience with wallpaper. The floor required just over 100 total work hours to cover 1,220 square feet, and was accomplished at a cost of one-fourth to one-third of the prices quoted by several professional installation companies.

Temperature Differences

One four-foot square section of glass was left bare to accommodate potted plants requiring direct sunlight. Using this section for comparison with the glass covered by film, it was possible to determine that a ten-degree reduction in temperature, measured twelve inches from the glass, has been achieved in the summer during the morning. In winter, even with no direct sunlight present, temperature was found to be three degrees warmer than previously, without the film.

Cost Analysis

Cost of the film was 85 cents a square foot, amounting to $1.00 per square foot when allowing for scrap. Later, in another area, the university installed less expensive solar film, but resulting appearance and durability were not as good.

Additional Advantages

An additional advantage of using the solar film is that it prevents shattering if the glass it covers is broken. This was particularly important in the library wall, which is elevated one story above a heavily used pedestrian walkway. Further, the solar film acts as a one-way mirror, allowing the room's occupants to look through the window without being seen.

Special Considerations

Presence of the solar film on the window is noticeable when observed from the inside; on a sunny day, the sky may appear to be overcast. Film-covered windows may be cleaned with a nonammonia-based solution and a squeegee. No rags or paper towels should be used since they can scratch the film.

State University of New York at Buffalo — Amherst Campus
Enrollment: 11,850

Caulking and Sealing Soffits

The university's Joseph P. Ellicott Complex opened in the fall of 1974 as a living-learning center combining academic and residential facilities. The 40-building complex ranges from three to ten stories, with multiple overhangs, and is located in the northwest corner of the new 1,200-acre Amherst Campus; it is virtually self-contained. It comprises 1,102,571 gross square feet, providing space for 3,200 residents as well as faculty offices, classrooms, libraries, a theater, and dining facilities.

The Amherst Campus is "total electric" and all dormitory rooms are heated by electric baseboard units with integral thermostats. The thermostats, while difficult to reach, can be adjusted by the room occupants. Unlike hydronic units, which allow some variance in water temperatures, these electric heaters are limited to a maximum output.

As occupancy of the complex increased, so did evidence of inadequate heat. Sixty-two locations were identified where additional heaters were required; these were installed.

There was also an inordinate incidence of frozen pipes in the complex. While it had not been expected that there would be a direct correlation between that problem and the lack of room heat, maintenance employees noted excessive cold air movement in concealed areas above the ceilings. Access holes cut in selected locations of soffit areas revealed that specified insulation was, for the most part, improperly installed or nonexistent. The reveal (opening) around the soffit perimeters permitted nearly free passage of cold winter air throughout the complex above the ceilings and in concealed spaces. It was later determined that there were 29,000 to 30,000 linear feet of reveal — nearly six miles of opening. Subsequent scanning with an infrared device verified excessive heat loss at all soffits.

Project Description, Justification

A project was scheduled for late fall to caulk the joints when they were at maximum opening and when the ground was sufficiently

---

Cost Analysis

	After Caulking		*Before Caulking*
Period	1/19/78 - 5/19/78		1/24/77 - 5/19/77
Heating Degree Days	4026 °Days		3047 °Days
Actual Consumption	19,740,000 KWHrs.		17,732,000 KWHrs.
1977 Consumption per degree day	$\frac{17,732,000 \text{ KWHrs.}}{3047 \text{ °Days}}$	=	5819.49 KWHrs. per °Day

If rate of consumption remained the same for 1978, then:

$$4026 \text{ °Days} \times 5819.49 \frac{\text{KWHrs.}}{\text{°Day}} = 23,429,283 \text{ KWHrs.}$$

Say: 23,429,300 KWHrs. could be expected.

23,429,300 KWHrs. anticipated
19,740,000 KWHrs. actual
3,689,300 KWHrs. saved

Average power cost for January — May 1978 = $.0268/KWHr.

$.0268/KWHr. x 3,689,300 KWHrs. = $98,873 saved in four months.

frozen to support a large aerial bucket truck. The pilot project provided sufficient encouragement to proceed with a request for funding to complete the entire project. This was estimated at $58,000. While cost benefit data were not available, the important obligation to provide adequate heat to resident students was sufficient justification to proceed.

Implementation

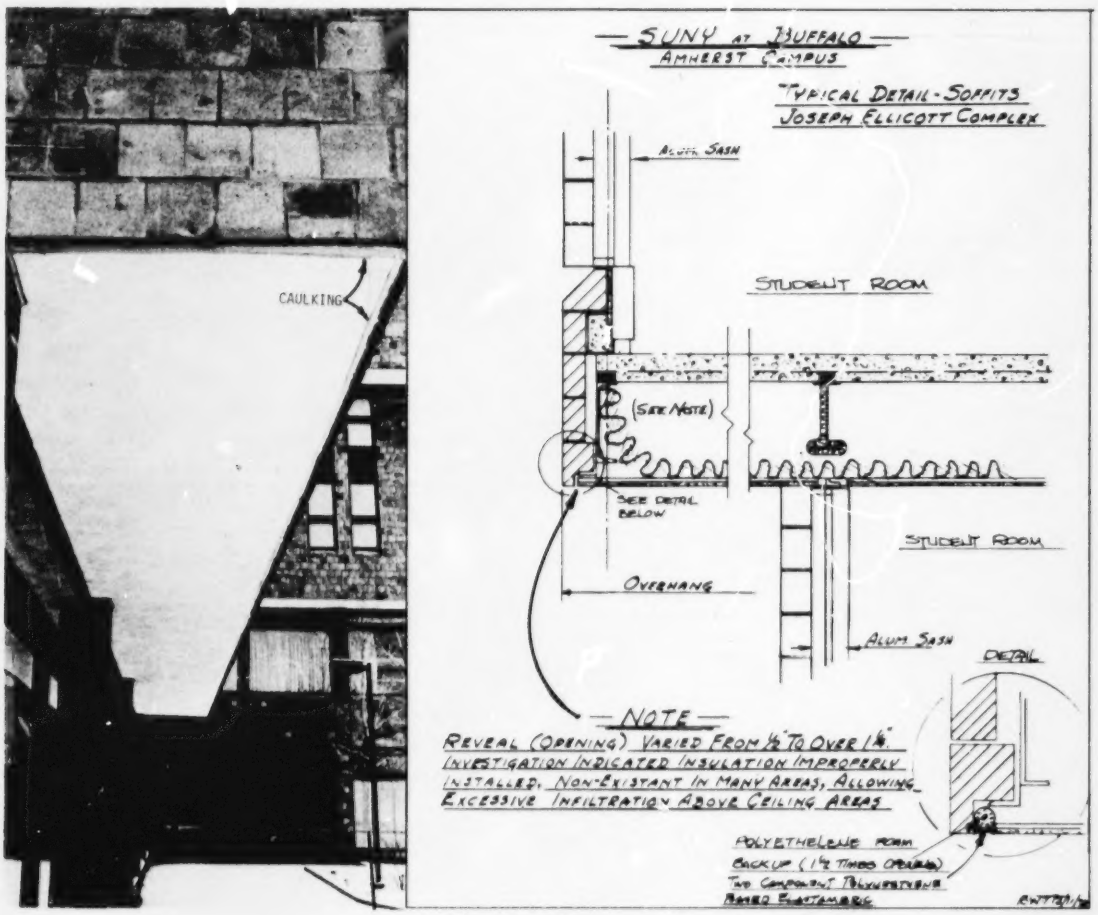
The physical plant staff, working in conjunction with a local contractor, Raymond E. Kelley Co., developed the scope for the pilot project. The same firm was successful bidder on the subsequent project. Basic specifications included the use of polyethylene foam strips or rods one and one-half times the size of opening as a backup material while the sealant material was a two-component polyurethane-based elastameric type.

Cost Analysis

The total project cost was $59,200, most of it funded by the Dormitory Authority of the State of New York. Savings were calculated on a degree-day basis with power use based on comparisons of actual meter readings for the four-month period after project completion.

National climatic data indicate that the above "sample" period normally represents only 60 percent of the annual heating degree days; therefore, additional savings could be expected, based on the entire heating season. Available data indicate savings of nearly $100,000 in the first four months following completion of the project.

While the problem corrected by this project may be unique to this campus, due to the large number of overhangs and miles of openings around them, it is significant proof of heat lost due to infiltration of outside cold air.



Milton S. Hershey Medical Center
The Pennsylvania State University
Hershey, PA
Enrollment: 479

Insulation

University Manor, a garden-style apartment complex for students and house officers, was opened in 1971 at the university medical center. The complex includes 248 one-, two-, and three-bedroom, all-electric apartments (including forced air heat, air conditioning, and all appliances) in 31 two-story buildings with four, eight, or twelve units in each building.

As a result of a heat-loss study completed in the spring of 1971 and rapidly escalating electric rates which increased 87 percent from July 1972 to January 1976, two insulation projects were tested: (1) side-wall insulation, and (2) attic insulation.

Test Project 1: Side-wall Insulation

The side walls of each apartment building are constructed of an exterior layer of hard brick, an inner layer of 4" concrete block, and an interior wall of hard brick. The exterior brick and inner concrete block are separated by a 2¼" cavity extending the full width and length of the wall. The thermal resistance of these materials was calculated in the heat-loss study to be a factor of 2.28. The study recommended that the cavity be filled with foam insulation to increase the thermal resistance factor to 9.45, reducing the heat loss in this area by 76 percent.

In the spring of 1976, an outside masonry contractor was hired to remove twenty-eight bricks from each of the two side walls on one test building. An outside insulation contractor was hired to spray "Rapco-Foam" into each opening to completely fill the cavity. The bricks were replaced, sealing the insulation in the side walls.

The annual electric usage for the test building before and after insulation was compared to the average annual electric usage for seven buildings of the same size during the same periods (each building is individually metered). This "cross comparison" eliminated any change in usage due to changes in degree days from one year to the next.

The comparison revealed a savings of 19,200 KWH in usage and $830 in costs as a result of the insulation. Project costs were $1,200, representing a payback period of 1.4 years.

Test Project Results: Side-Wall Insulation

	Electric Use (KWH)		
Before Insulation	Test Building	Average for 7 Same Size Bldgs.	Test Building Over (Under) 7 Bldg. Avg.
Total — 12 months	204,100	205,200	(1,100)
After Insulation			
Total — 12 months	199,400	219,700	(20,300)

Analysis

KWH Under Average After Insulation	20,300	KWH Savings x Average Rate (May 1976-April 1977)	19,200 $.0433
Less: KWH Under Average Before Insulation	1,100	$ Savings	$831.36
KWH Savings Due to Insulation	19,200	Project Costs	$1,200.00
		Payback Period	1.4 years

Test Project 2: Attic Insulation

Several months after completion of the side wall test project, the insulation in a number of attic spaces was inspected. The inspections revealed missing or sagging 6" fiberglass batts and gaps between the batts and the ceiling joists. In November 1976, an outside insulation contractor was hired to replace missing batts, repair sagging batts, and fill gaps with pouring wool in one test building.

The electric usage for seven months before completion of the project and the electric usage seven months after completion of the project was compared to seven other buildings of the same size for the same periods. As in the side-wall test project, this "cross analysis" eliminated any change in usage due to changes in degree days. The comparison revealed a savings of 13,650 KWH in usage and $560 in costs as a result of the

project. Project costs were $630, representing a payback period of 1.1 years.

Test Project Results: Attic Insulation

	Electric Use (KWH)		
Before Insulation	Test Building	Average for 7 Same Size Bldgs.	Test Building Over (Under) 7 Bldg. Avg.
Total — 7 Months	151,500	147,200	4,300
After Insulation			
Total — 7 Months	148,700	154,900	(6,200)

Analysis

KWH Under Average after Insulation (7 months)	6,200
Add: KWH Over Average before Insulation (7 months)	4,300
KWH Savings Due to Insulation (7 months)	10,500
x Factor to Annualize $1 + \frac{63,000}{210,200}$	1.3
KWH Savings Due to Insulation (Annual)	13,650
KWH Savings	13,650
x Average Rate (December 1976-June 1977)	.041
$ Savings	$559.65
Project Costs	$630.00
Payback Period	1.1 Years

Project Expansion

Based on the low payback period and the prospects for even greater energy and cost savings in the future, the decision was made to expand the projects to the thirty remaining apartment buildings. Funds for the project were encumbered against an equipment replacement and projects budget established by the university for the apartments.

The projects were completed in December 1977 at an additional cost of $26,200 ($18,400 for the side-wall project and $7,800 for the attic insulation project) increasing total project costs to $28,030. The only change in specifications was that the low bidder on the side wall project used "Celsius" rather than "Rapco-Foam" insulation.

Final Results

A comparison of the combined electric usage and costs for all University Manor buildings before insulation (1976-1977) and after insulation (1977-1978) reflects savings of about 649,000 KWH in usage and $25,000 in costs.

Special Problems

The university's design and engineering staff warned of the possibility of moisture condensing in voids if the foam insulation was not continuous. The staff recommended that care be exercised in the choice and spacing of openings for the pressure nozzle. As a result of this recommendation, it was decided to remove twenty-eight evenly spaced bricks to assure that the void was filled completely. The insulation contractor pumped insulation into each opening until it could be seen in the surrounding openings. To date, no moisture problem has been reported.

The side-wall project specifications were written based on the 2¼" cavity in the test building. Soon after the insulation contractor began work, he found that many cavities were greater than 2¼" in size and he requested additional funds to complete the work.

Massachusetts Institute of Technology
Cambridge, MA
Enrollment: 8,597

Window Caulking

The original buildings of the institute, known as the Bosworth Group, have been in service for sixty-two years. The buildings have double-hung, steel sash windows that are no longer sufficiently air-tight. Five hundred ninety-one of these windows were caulked in November with a flexible, putty-like material called "Mortite"; this was removed in April. This caulking is easy to apply and the cost is low enough to permit reapplication each fall. Two hundred windows in corridors and similar areas were left permanently caulked.

Justification, Implementation

The caulking was justified by basic calculations for the heating load due to infiltration of cold outside air:

$Q = Q \cdot Cp \cdot \gamma$
$= Btu/ft\text{-}°F\text{-}Hr$

where: Q = Infiltration — Cubic feet per ft-hr
Cp = Specific heat — Btu per lb-deg F
γ = Density — lbs/ft^3

$Q_{season} = (Btu/ft\text{-}°F\text{-}hr)\ (Feet\ of\ crack)\ (t_i\text{-}t_o)\ (Days\ of\ Season)\ (24)$

where: t_o = Average outside temperature
t_i = Inside temperature

From the above, a seasonal loss per window can be established for the uncaulked windows. Assuming that the caulking was 90 percent effective, annual savings would be 90 percent of the calculated loss due to infiltration. Considering the entire building envelope and not an individual window, the actual infiltration would be 50 percent of the total infiltration and the previously calculated savings should be reduced by 50 percent.

The installation was made by a local contractor who is otherwise employed by MIT to clean venetian blinds. The program was not mandatory; office occupants who did not wish their windows caulked were permitted the option of opening their windows. Restroom windows were not caulked.

Cost Analysis

The cost of caulking a window was $14 (labor and material), to which must be added the spring removal cost of $2.50 per window, making a total cost of $16.50 per window. The net actual saving comes to $7.48 per window or a total of $4,418 per season. Although there are no operating data to verify the calculated savings, it is felt that substantial savings do exist. Moreover, the increased comfort due to fewer drafts cannot be evaluated in terms of money.

Carleton University
Ottawa, Canada
Enrollment: 14,656

Task Lighting Conversions

Most of the university buildings were designed and built before the energy crisis and before the financial restraints on university operating budgets in Ontario. The overall level of illumination in these buildings was high, often achieved by uniform ceiling fixtures across an entire space, regardless of need or distance of the light from localized working surfaces. Yet, faculty offices and other single occupancy spaces typically have daylight illumination from windows; depending on window areas and orientation, very little artificial light is needed for much of the day, during most of the year, in those spaces.

Project Description, Implementation

The above considerations were used as a basis for a new approach to lighting and energy conservation:

1. Localized lighting was introduced in spaces such as offices or lounges where a higher level of illumination is needed within a restricted working area. Uniform lighting was maintained in spaces such as classrooms and laboratories with high intensity lamps where necessary.

2. Distance between light source and working surface affected the lighting method, such as a case where a higher level of illumination is needed to perform a specialized activity in a room lighted to lower standards.

3. Natural daylight was found to provide adequate illumination in a standard faculty office. Such an office has window space from desk level to ceiling on one side, with variable levels of illumination measured in one case from 1,000 lux beside the window to 600 lux 2.0 meters from the window and as low as 300 lux close to the wall, opposite the window.

In the past, the university had replaced natural light by a uniform 750-lux fluorescent illumination. Now it uses daylight as far as possible, providing supplementary lighting in offices (120 gross square feet in size) that consists of two 40-watt tubes in a ceiling fixture plus one 32-watt circline fluorescent tube in a task lamp; the latter sometimes replaced by a drafting lamp of two 15-watt tubes. This is a total of 110 watts.

Nearly 700 task lamps were installed by crews of custodial personnel in most offices in three facilities. The university funded the project as a capital expenditure; installation used ordinary operating funds.

Cost Analysis

A cost analysis per office is as follows:

Expenditures	— one task lamp, 32-watt opal acrylic enclosure	$46.56	
Yearly savings	— ten 40-watt tubes removed @ $2.50	25.00	
Pay back period	(energy cost constant)	22.3	months

Considering that the offices already had reduced their as-built lighting to four fixtures, 2 x 40 watts each, because of previous reduction policies, the real payback would read as follows:

Yearly savings (six 40-watt tubes removed @ $2.50)	$ 15.00	
Fifteen-year life net savings, (per office)	178.44	
Project savings per year (700 lamps x $15.00)	10,500.00	
Project net savings over fifteen-year period (lamp life expectancy)	124,908.00	
Payback period (energy cost constant)	37.2	months

Dartmouth College
Hanover, NH
Enrollment: 4,188

Retrofit Lighting Project

The institution's Nathaniel Leverone Field House, completed in 1961, was equipped originally with 84,000 watts of high-bay fluorescent fixtures mounted in continuous strips against the curved concrete roof. Artificial turf was installed in 1971, and forty 400-watt metal halide fixtures were added to augment light levels over six newly created tennis courts. Switching of the lighting was such that nearly all 100,000 watts had to be used in order to achieve adequate lighting throughout the building. Total area covered by the facility is 93,600 gross square feet.

Project Description, Implementation

During the summer of 1976 all the metal halide fixtures and all but the lowest strips of the fluorescent lights were removed and replaced with fifty-two high-pressure sodium fixtures, consisting of twenty-four 1,000-watt lamps, fourteen 400-watt lamps, and fourteen 250-watt lamps. At the same time, four widely separated electrical panels were abandoned in favor of a central control box that divides the illumination into five sections, each controlled by a single push button. Lighting levels were increased from approximately 45 foot-candles to 65.

The forty 400-watt metal halide fixtures removed from the Leverone Field House project were used to replace 30,000 watts of incandescent lighting in the basketball arena of nearby Alumni Gymnasium. At the time, the floor area was being doubled in size by the use of roll-out bleachers in place of fixed seats. Once the new metal halide lights had been installed over the two new floors, each area with its own switch, foot-candle levels were found to have increased from 75 to 90.

Fixtures were purchased and installed by the department of buildings and grounds. The low bidder for the fixtures was General Electric for Filterglow, single, integral ballast fixtures equipped with Lucalox lamps. Globe strut fixtures were used for hangers, and Allen-Bradley supplied push buttons and the central control panel, as well as contactors. Fixtures were raised in place and hung by the use of a college-owned 75-foot lift. The lighting layout was designed by college personnel. Six fixtures were obtained "on loan" and hung in different patterns so that light intensity and evenness could be measured and adjusted.

Funding, Cost Analysis

The project was funded by borrowing money from general college funds and paying it back with interest in thirty-six equal monthly payments, charging the payments to the electrical bill for the facility. At the end of three years, the electrical budget will be reduced by the amount of the annual payments.

Project costs for retrofitting the lights in Leverone Field House at the time of construction were estimated to be $25,000. Annual savings in electrical costs for the facility were estimated to be $8,000. Since the cost of electricity purchased by the college in the six years prior to the project had increased more than 20 percent annually, no allowance was made for the cost of borrowing money to finance the job. Thus the simple payback was figured at 3.1 years. Since savings in nearby Alumni Gymnasium were estimated to be approximately $2,000 per year, this would have substantially decreased the payback period, if considered.

The project was completed in the summer of 1976. The average electrical usage of the facility for the six years prior to installation was 326,468 KWH. In the two years since installation, annual usage has averaged 139,650 KWH, a saving of 186,818 KWH annually. It is estimated that approximately 15 percent of the latter figure, however, is a result of other energy conservation programs, leaving a saving of 160,000 KWH annually as the result of the lighting project. At current rates this amounts to an annual return of $7,680. Since the final project cost was $24,677, the actual payback is 3.2 years, again assuming the cost of electricity has increased faster than the cost of money, and ignoring the additional savings accrued from using the old fixtures in Alumni Gymnasium.

Western Michigan University
Kalamazoo, MI
Enrollment: 20,617

Relighting Intramural Gymnasium

The intramural gymnasium, comprising 28,792 square feet, had been lighted by sixty twin incandescent fixtures mounted in rows approximately thirty feet above a wooden floor. Each fixture was specified to contain two 1500-watt lamps, but only 1000-watt lamps were used. In January 1977, sixty twin fixtures were replaced by sixty single 400-watt high-pressure sodium lights.

Project Description

The gymnasium contains four basketball courts and is in use, including custodial clean-up time, ninety-seven hours per week. When all 120 incandescent lamps were lighted, the total weekly electrical load was:

120 lamps x 1000 w/lamp=120 KW
97 h/wk. x 120 KW=11,640 KWH/wk.

With an electrical rate of $.031/KWH the calculated weekly cost of lighting the gymnasium was:

11,640 KWH/wk. x $.031/KWH=$360.84/wk.

Incandescent fixtures were removed and sixty new high-pressure sodium fixtures were installed by the university's own physical plant electricians. The lighting level remained about the same, 58 foot candles, and continued to give the gymnasium a warm, pleasing appearance. Because each twin fixture was replaced by a single unit, the lighting pattern remained the same.

Electrical load using high pressure sodium lights:
Ballast—65 watts
60 lamps x (400 + 65) w/lamp=27.9 KW
97 h/wk. x 27.9 KW=2706.3 KWH/wk.

If the electrical cost is assumed to be the same, $.031/KWH, the weekly cost is:

2706.3 KWH/wk. x $.031/KWH=$83.90/wk.

Savings per week: $360.84—$83.90=$276.94

Justification, Savings

The relighting project was justified because the payback would occur in less than one year. The cost of fixtures, materials, labor, etc. to relight the gymnasium totaled $9,637.72. Assuming year-round use, the investment in relighting was returned in nine months of operation. The project was financed by funds designated by the university for energy conservation.

There are additional savings in that only 60 (rather than 120) lamps require maintenance. Incandescent lamp life is rated at 1,000 hours (2,300 hours for extended service lamps), compared to 20,000 hours for high-pressure sodium lamps, resulting in fewer replacements.

Other Considerations

No special problems were encountered, but persons interested in similar installations may wish to consider the stroboscopic effect, or flicker, on rapidly moving objects. However, this can be minimized if lamps are connected to alternate phases of a three-phase supply.

Those who use the university gymnasium have expressed pleasure with the quality and quantity of lighting. After this project's success, 107 high-pressure sodium fixtures were installed to relight four additional high-bay areas, with equally gratifying results.

Massachusetts Institute of Technology
Cambridge, MA
Enrollment: 8,597

Variable Air Volume in Hermann Building

The air conditioning system installed in the Hermann Building during original construction in 1965 was a constant volume, dual-duct system with air valves set for 25 percent minimum air flow. A total of 136 mixing boxes cover 94,400 gross square feet on four floors and a basement area. A single supply fan and a single return fan operated to circulate 104,000 CFM supply air and 91,000 CFM return air. Total horsepower was 100 supply and 30 return.

A contract was negotiated with the facility's original air valve supplier to replace all the air valves on 100 mixing boxes used for exterior zones with new "tight shutoff" valves and to remove hot deck valves on 36 interior zone mixing boxes. Further, the fan speeds were reduced and existing motors were replaced with smaller horsepower units. Central monitoring and control were added as part of a larger, campus-wide program and optimization programs were instituted concurrent with the air system changes.

Cost Analysis

The analysis for payback, included with the original proposal, was for savings on motor horsepower approximating $5,900 per year and savings on total steam consumption for heating and cooling of $37,000 per year, for a combined total of $42,900. The estimated costs for air system work were $46,500 in direct contracts and $5,000 of indirect costs. Costs for central computer control have not been included. Actual annual savings have averaged $41,400 to date.

The work was completed by outside contractors, with some technical direction from physical plant personnel. Design detail was minimal since new equipment was limited to replacements of smaller size. Work on systems was performed at night during unoccupied periods. A weighted damper was installed to permit the relief of excess air from the discharge plenum prior to the actual speed change of the supply fan. Total elapsed time for completion was approximately six weeks.

The project was funded out of current operating costs — specific reserve accounts set aside for special major repair projects. Projected savings indicate a fifteen-month payback.

Special Problems

Special problems were encountered when the return air quantities were found to be out of balance and many room thermostats required recalibration. Perimeter radiation from hot water finned convectors upset some areas until water balance was reset to a better schedule.

The Pennsylvania State University
University Park, PA
Enrollment: 38,691

Natatorium Heat Recovery (Glycol Runaround System)

The university installed a heat recovery system in its Natatorium, (which comprises 73,644 gross square feet and contains three swimming pools) that extracts heat from hot, humid exhaust air and transfers the heat to colder make-up air. Exhausting the humid indoor air and introducing equal amounts of tempered outdoor air prevent excessive humidity build-up and associated condensation from forming on the pool area walls and ceilings during cold weather.

Funding, Design

The installation, which was accomplished by university employees, was funded from the institution's operating budget. Cost of implementation was $19,525, with estimated payback of two years.

Space limitations precluded the use of a heat recovery wheel; however, the existing facility was ideally suited for a runaround system application.

Important statistics are:

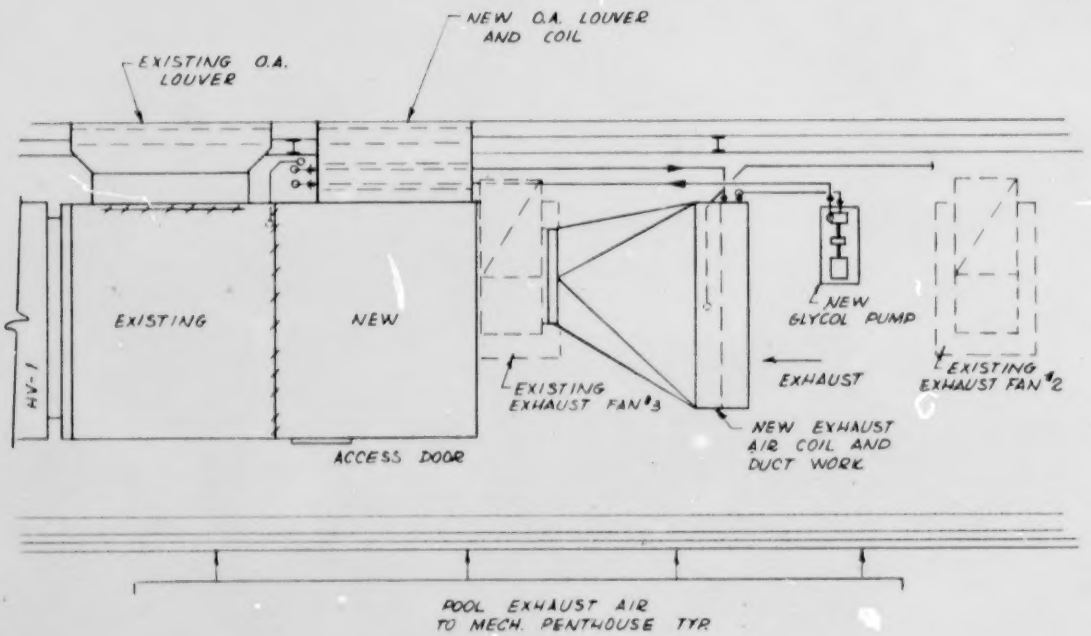
Exhaust coil — 18,600 CFM, 75/68 EA, 39° EWT, 40% glycol, 100 GPM, 0.63″ APD, 13.1′ WPD, 825 MBH.

Fresh air coil — 18,600 CFM, 0° EDB, 59° EWT, 40% glycol, 100 GPM, 0.86″ APD, 12.8′ WPD, 825 MBH.

Operation

During winter operation, outdoor air requirements are kept to a minimum. When the outdoor temperature is below 60° F. and the pool area is above 50 percent relative humidity, the heat recovery system becomes operational. All controls and set points are adjustable.

Natatorium Heat Recovery



Washington State University
Pullman, WA
Enrollment: 16,693

Heat Reclaim System

A heat reclaim system for Johnson Hall, a large (193,400 gross square feet) laboratory and office building, was one of various projects listed in priority order in an energy conservation program begun in 1974 for the university. Johnson Hall utilizes a classic dual duct HVAC system with 100 percent outside air. The heat reclaim project promised a relatively short payback period (less than five years) at a moderate total expenditure (both East and West Reclaim Systems) of $100,000.

Funding and Planning

The university prepared a detailed economic justification in coordination with a request for capital funds and in 1976 was enabled to proceed in-house with final design drawings and specifications. It was planned to begin with installation of the East Reclaim System and then proceed to installation of the West Reclaim System, using what had been learned in the first experience. Construction for the East Reclaim System, a $46,800 project, began in August 1977 and was completed in November 1977.

Design, Operating Details

The physical proximity of the exhaust and supply plenums (see Figure 1) was especially advantageous, since the objective of the system was to recover heat from the exhaust plenum (that would otherwise be wasted in the 100 percent outside air system) and reintroduce the recovered heat into the supply plenum. The proximity of the supply and exhaust reclaim coils meant that the glycol heat transfer medium would be kept at a low volume, in turn minimizing the BTU line loss and therefore increasing the recovery efficiency.

The piping system consists of a basic set of components; major elements are the 10 horsepower circulating pump, chemical treatment apparatus, expansion tank, and various valves and air purge vents. Although pump and coil sizing were expedited through using commercial computer programs, a significant portion of the design effort came from in-house engineering staff.

Control of the reclaim system (see Figure 3) is local, using outside air temperature (TS-1) to start the circulating pump when the temperature falls to 45°F. and using a modulating control valve (V-1) to control preheat supply air temperature at a maximum of 55°F. A secondary thermostat is required to insure a return temperature (to exhaust coil) of at least 30°F. to prevent coil freeze-up. A similar control scheme is used during the cooling season so that the chilled exhaust air can be effectively reintroduced into the supply system when the outside air temperature exceeds 80°F.

The vital signs of the reclaim system can be read locally and also remotely at the central HVAC control console. The Central HVAC Control and Monitoring System (Powers 570) facilitates the automated logging of entering and discharge glycol temperatures as well as entering and discharge air temperatures in both the supply and exhaust reclaim components. An analysis of the accumulated central control data reveals the BTU transfer from the exhaust to the supply

Figure 1: East Mechanical Space

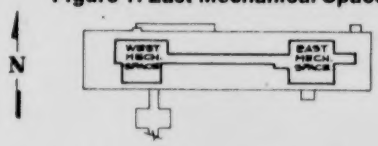
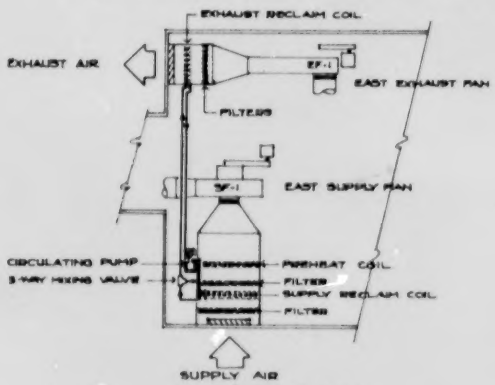


Figure 1a: Johnson Hall Penthouse Plan



Johnson Hall

Figure 1b: East Mechanical Space

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system which is equivalent to the total heat reclaimed. As an example of the efficiency of the system, at an outside air temperature of 35° F. the system is capable of reclaiming 825,000 BTUs per hour which, incidentally, is sufficient to satisfy the entire space heating demand on the East System.

Cost Analysis

An analysis comparing the installation and operating cost of the subject system to the actual value of the heat reclaimed has revealed that initial estimates were conservative. The actual net value of heat reclaimed in Johnson Hall's East Heat Reclaim System during the 1977-78 heating season has an equivalent annual dollar value of $15,500. Considering the initial installation cost ($46,800), the payback period for the project is three years.

Due to the positive results of installing the East Heat Reclaim System, a twin system, completed in October 1978, was installed in the West Supply System, costing $48,700. Indications are that results from the new installation will equal those of the East System, with an annual savings of $31,000 attributable to both systems, or total savings of $524,500 over twenty years.

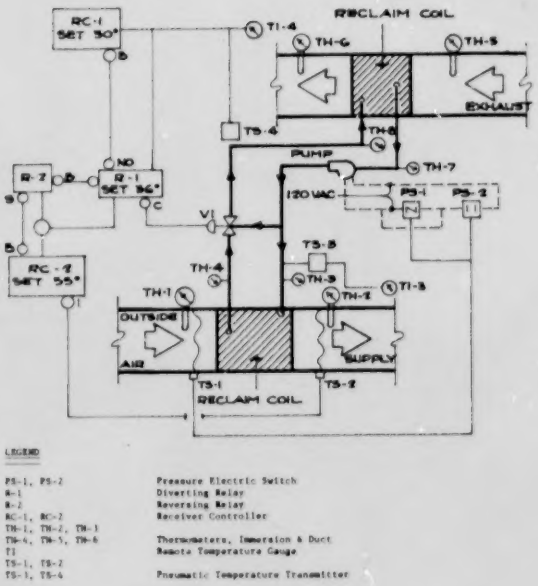
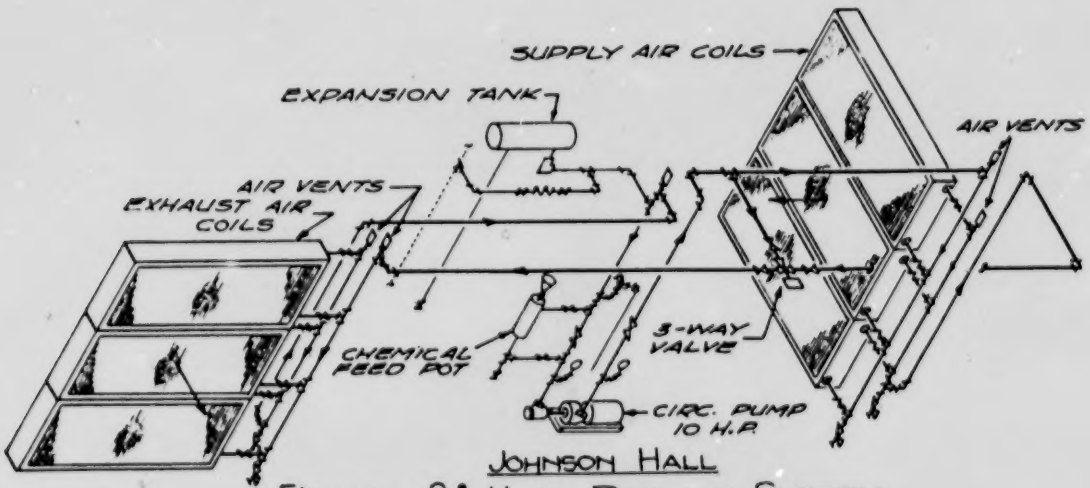


Figure 3: Heat Reclaim System, Control Diagram



JOHNSON HALL

Figure 2: HEAT RECLAIM SYSTEM PIPING SCHEMATIC

Syracuse University
Syracuse, NY
Enrollment: 19,926

Heat Recovery from Steam Condensate

In the major campus dormitories served by the university's campus steam station, heat exchangers were installed on the domestic hot water tanks to use steam condensate as a supplemental heat source to the live steam operation.

Justification

Condensate returning to the steam station loses a portion of its heat to the ground. Some lines are three-quarters of a mile long, causing the condensate temperature to drop from about 200°F. to 130°F. by the time it reaches the station. With the heat recovery project, this heat will be recovered before the condensate leaves the building with no additional burden on the steam station. The estimated payback on the heat exchangers from the various buildings ranges from 1.2 to 1.6 years, at current steam rates.

Project Design Details

The composite diagram opposite shows the existing system (in fine lines), the added equipment (in heavy lines), and the piping removed during modification (in dotted lines). The conversion (heavy lines) routes the water flow through the heat exchanger in series with the circulation pump. A new high-limit aquastat in the circulation loop controls water flow, while the building steam condensate is rerouted through the exchanger and back to the existing condensate sump. The existing aquastat on the live steam valve is readjusted to a low limit operation only.

The new system now maintains water temperature between 120°F. and 150°F., using the steam condensate as a heat source. If water temperature rises above 150°F., the circulation pump turns off and condensate is allowed to pass through without heat recovery. If building demands for hot water are greater than condensate can supply and the temperature drops below 120°F., the live steam valve opens to maintain temperature.

Cost Analysis

The heat recovery project was funded through the Department of Housing and Urban Development's College Housing Loan Program and is being accomplished by contract, based on competitive bid, at a cost of $33,000. This payback period of 1.2 to 1.6 years was calculated at a steam rate of $5.50 per thousand pounds and shows annual savings of between $2,700 and $4,700 for various dormitories. With steam costs rising at about 15 percent per year, the twenty-year cost avoidance would be substantial.

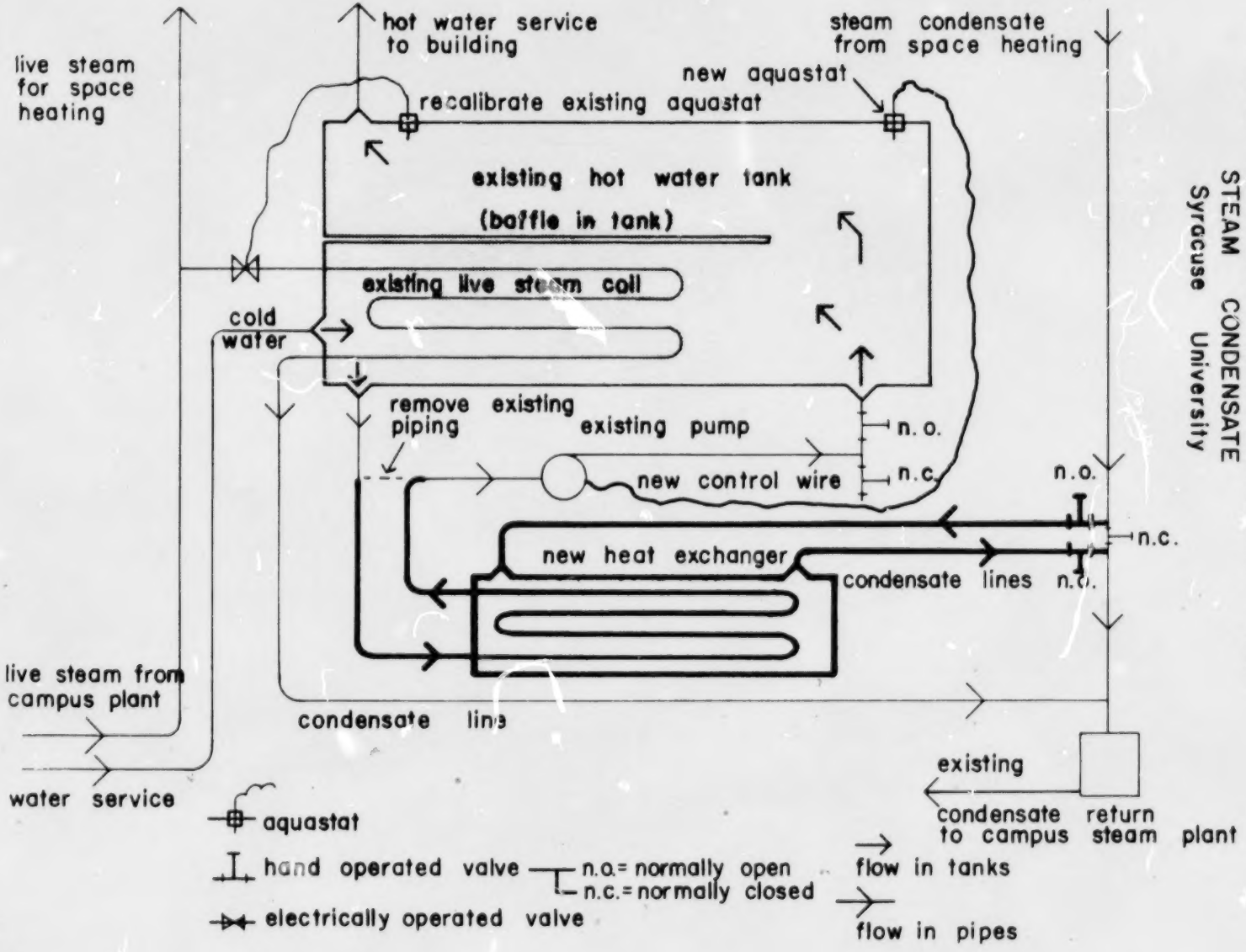
Special Considerations

It should be noted that this system is designed for centralized steam plants, rather than buildings with local boilers. Condensate line heat losses would not be large enough to justify heat recovery.

(See diagram opposite)

DOMESTIC HOT WATER HEAT RECOVERY FROM STEAM CONDENSATE

Syracuse University



St. Louis Community College at Meramec
St. Louis, MO
Enrollment: 9,998

Multi-Zone Control

The institution modified multi-zone unit controls to reduce outside air, lowered hot deck settings in air handling units, lowered secondary hot water temperature settings, raised cold deck temperature setting in winter, and modified controls in the winter cycle for perimeter unit ventilators and single zone air-handling units — this prevents introduction of outdoor air until the heating control is fully closed and room temperature is above set point.

Justification, Design, Operating Details

Energy savings are achieved as a result of reducing quantities of outside air used in winter, lowering temperature settings in heating water systems, and reducing the amount of reheat required for single and multi-zone units. The annual savings in gas (52,800 therms) and electric power (320,000 KWH) result in a 0.5 year payback.

Design calculations were provided by an outside energy consultant and the control modifications were accomplished through a contract with a control company. Only minor changes or additions were made in the existing control systems. Almost no new equipment was required. Many changes were simply adjustments to original settings. (It is important that changes are recorded on original control drawings and schematics.) Multi-zone unit controls were modified by setting mixed air set point at 60°F., up from 55°F. The system was changed to permit the central control panel to adjust the set point in a range from 68°F. to 54°F. Hot deck controls are automatically reset from 90°F. at 20° F. outdoors and colder to 75°F. at 60°F. outdoors and warmer. The central control panel can reset 10°F. higher and lower. The hot water system is modified to range in temperature from 120°F. to 90°F. as outdoor temperature rises from 20°F. to 60°F. Single-zone air handlers and classroom-unit ventilators control cycles are being modified to prevent introduction of outdoor air until heating control is fully closed and room condition is above control set point (70°F. winter). The cold deck temperature setting was changed from 55°F. to 60°F.

Cost Analysis

The project was financed by special capital energy funds, with design and modification work costing $8,538. Annual savings (1977 rates) are estimated at $17,340. This means a payback period of 0.5 years.

University of Pittsburgh
Pittsburgh, PA
Enrollment: 29,444

Benedum Hall HVAC System Modifications

Benedum Hall is a fourteen-story engineering building, with an area of 424,000 gross square feet, constructed in 1970. It contains laboratories, classrooms, offices, plant services and building maintenance division offices and shops, and a large auditorium. The facility used an average of 12 million KWH of electricity annually and an unknown quantity of steam through 1973.

The building is heated and cooled by central steam and two 750-ton centrifugal chillers through a dual-duct, mixing box system. The building chillers and air systems operated twenty-four hours a day, every day, due to the high core cooling load, which was caused primarily by a lighting level of 120 foot-candles. A brief study of the facility revealed that this continuous illumination, heating, and cooling was excessive, since classrooms and offices were occupied only from 8:00 a.m. to 10:30 p.m. and few laboratories required cooling twenty-four hours a day for each day in the year.

The air system was designed to admit a minimum of outside air and would require major renovation of ductwork and outside and exhaust air openings to be converted to economizer control. Since it was not possible to introduce a significant amount of outside air for cooling during winter, the alternative was to reduce the cooling load.

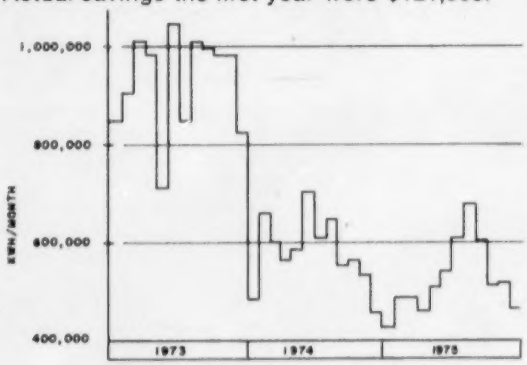
Conservation Measures

As a result of the building study, the following measures were taken to conserve energy and maintain the environmental conditions necessary to the educational and research mission of the facility:

1. About 50 percent of the lamps were removed from core rooms, lowering the lighting level to 50 foot-candles.
2. Seven primary fans with a rating of 525 horsepower were slowed to reduce air flow by about 25 percent and power requirements by 200 horsepower.
3. Chillers were shut down at night during the summer and from about mid-October to mid-April.
4. All fan systems were shut down from 11 p.m. until 7 a.m., seven days a week, except during extremely warm weather when all fans and chillers were in operation twenty-four hours a day.
5. The temperature of the hot deck was reduced to 85°F. and the cold deck temperature was raised to 60°F. There are no requirements for precise humidity control in the building.
6. A new 55-ton chiller, distribution piping, and fan coil units were installed to serve spaces that have a high and continuous cooling load.

Project Justification

The project was justified by an engineering and economic study of facility heating and air conditioning systems and of the actual requirements for facility heating and air conditioning. All major power-consuming equipment was identified and the total annual power requirements were estimated by manual methods. Manual calculations were repeated, using the reduced running hours and other assumptions mentioned above, and the estimated savings were $120,000 a year. Actual savings the first year were $121,000.



Implementation and Funding

Installation of the new core cooling system was performed by an outside mechanical contractor. All other work, including the preparation of plans and specifications, was performed in-house.

The project indicated a payback period of about six months and was funded totally by the university from its operating budget.

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St. Louis Community College at Forest Park
St. Louis, MO
Enrollment: 6,761

Modification to Supply, Return, and Exhaust Air Systems

This project reduces the amount of air that must be heated and cooled by reducing, to a minimum safe level, the amount of outside air supplied to the institution's heating, ventilating, and air conditioning system. This is accomplished by adjusting dampers and controls on outside air intakes; adjusting fans and zone controls, exhaust air systems, and air volumes; and delaying morning start-up of heating and air conditioning systems.

Justification, Installation Details

The project was justified by delayed start-up savings of 56,000 therms annually, low occupancy-mode savings of 500,000 KWH annually, and reduced outside air savings of 70,000 therms and 145,000 KWH annually. College maintenance and operations staff accomplished the work. This included, in all towers in east and west wings and in gymnasium and theater buildings, adjusting minimum outdoor air and return air and relief air dampers at each supply air system; adjusting return air fan performance; and adjusting performance of zone control air boxes (balance system). In the welding and foundry areas and in the auto shop, exhaust fan controls were separated from supply fan controls (interlock was removed and separate start/stop switches were installed for exhaust fans). A throttling discharge damper was added on the welding and foundry installation for high/low flow conditions. In the welding laboratory and forge shop, chain-operated dampers were added in the ducts. In the auto laboratory, manual throttle was added on the exhaust and a balancing damper was added to the welding hood. Preheat coils were disconnected on units with reduced outside air quantities.

Final Cost Analysis

The project was financed from special capital energy funds. The engineering cost was $20,000 and work by college maintenance and operations staff is estimated to cost $2,980. Annual savings are estimated at $31,850 (1977 rates), with a payback period of 0.7 years.

Special Problems

Extreme care must be exercised to protect chilled water coils when disconnecting preheat coils to prevent coil freeze-up in winter.

North Texas State University
Denton, TX
Enrollment: 17,018

Time Clock Installation

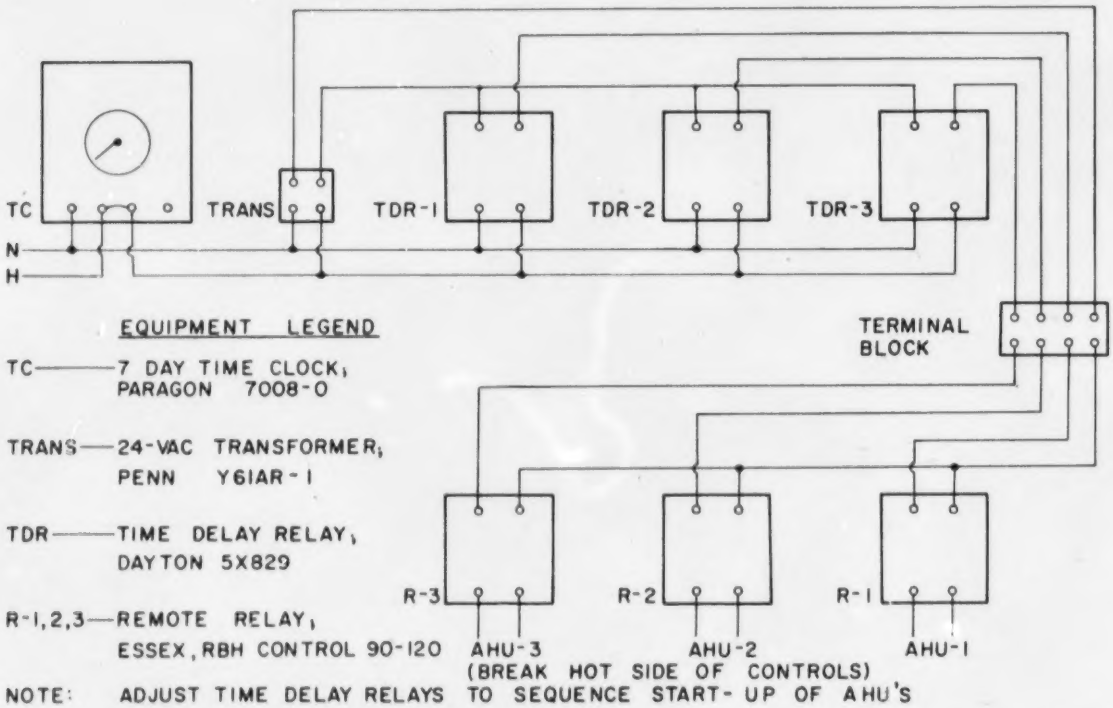
A seven-day, twenty-four-hour master clock and the necessary number of time relays were installed in each of several buildings to regulate the heating, ventilation, and air conditioning systems. This installation is unique in that only one clock, with its relay system, is used to control multiple pieces of equipment in a building. The installation permits control of HVAC building systems to be off or reduced during unoccupied periods both for hours per day and days per week. Exempted are certain academic buildings where large temperature variations would adversely affect experiments or extremely sensitive equipment.

Justification and Implementation

Justification of the project was based on extremely high utility costs and the comparatively low installation cost of this time clock system. The project was accomplished in-house by physical plant employees using equipment purchased by the university.

Funding, Cost Analysis

The project was financed by university funds. Project cost was estimated at $8,000, with a cost rate payback of one month. This was accomplished. In a one-year period, the university reduced its utility cost by $300,000.



TYPICAL WIRING DIAGRAM TO SEQUENCE START-UP OF AIR HANDLING UNITS AFTER SHUT-DOWN AT NORTH TEXAS STATE UNIVERSITY, DENTON, TEXAS

Lane Community College
Eugene, OR
Enrollment: 7,445

Computer Management, Peak Power Control, Energy Recapture Systems

The Lane Community College campus includes sixteen different buildings with more than 700,000 gross square feet of space. Heating and cooling are centralized in a single plant that is totally electric. For three years, the college had been involved in typical energy conservation activities, such as turning off lights, relamping, curtailing hot water use, increasing mixed air temperatures, reducing outside air intake during nonuse periods, etc. These measures were effective in reducing total energy consumption, even though several new major buildings were added to the campus. However, rate charges for electricity offset consumption reductions so these efforts had little budgetary impact.

The institution's cost of electricity is dependent not only on consumption but also on demand (the highest use of electricity in any one fifteen-minute interval during the billing month). This demand rate was observed to have a significant effect on the total cost of electricity to the college, yet there was virtually no way to control its level without intensive manual monitoring. The problem was exacerbated by lack of funds and a commitment of remodeling and construction funds to various high priority projects. A shortage of cooling capacity also had existed for a number of years. Further study of the HVAC system identified the obvious loss of heat from the air conditioning system's cooling tower, as well as from keeping buildings heated all the time to avoid sudden increases in demand with the concomitant increase in costs. A solution was sought to control excessive demand-based charges, reduce costs, recover lost heat, add cooling capacity, and achieve utility-imposed reductions.

In the fall of 1975, information was gathered toward such a solution, including consultations with other institutions and vendors of computerized controls. An engineering firm was retained to study the institution's HVAC system, review vendor proposals, and recommend different courses of action with price estimates. A proposal resulted to implement a modification and addition to the institution's central heating and cooling plant; the alteration would cost more than one quarter of a million dollars.

Funding, Justification

No uncommitted funding for a project of this magnitude existed. Therefore, the administration and college committees, and ultimately the board of directors, were asked to allow funds to be loaned to this project, to be repaid from budget savings released from the energy budget in future years. The payoff rate was estimated at that time to be less than three years.

Project Description

The project consists primarily of three components: computerized controls, an energy recovery unit, and energy storage. The controls, including a Honeywell Delta 1000 minicomputer, monitors the environment in each zone within each building and makes decisions to enhance the environment in the most energy-effective manner possible. Included with the startup, shutdown, and mixture decisions are those that preclude the electric demand from reaching peaks that create unusually high energy charges. The energy recovery unit, a chiller in principle, removes heat from the existing cooling system and, rather than exhausting this heat through the cooling tower, returns it to the heating system for use as heat where needed at other campus locations. Heat produced from the refrigeration cycle is available at a lower cost per unit than heat from the institution's two electric boilers.

The third major component of the system is the storage of energy in the form of hot water in large tanks. This energy storage allows the operation of the boilers to heat water in off-hours when other electrical use on campus is low; ultimately, the heated water can be used for facility heating during peak demand periods. The demand can, therefore, be kept relatively constant, rather than peaking and driving costs upward. The

storage of energy also enhances the use of the energy recovery unit at times when high cooling demand does not coincide with times of heat demand. The heat recovered from the cooling cycle can, with the storage devices, be reused at a later time when needed. Energy storage also allows the shut-off of heat sources to buildings at night as the stored heat can be used for start-up without causing the electric demand to peak. In the past, heating the buildings all night and on holidays was less expensive than shutting down and then reheating just prior to use, since the cost of the lost heat was less than the demand charges incurred by reheating.

As components were being ordered for the system, the college excess property coordinator located two large liquid oxygen storage tanks near Los Angeles; they had been used in the space program. The tanks were similar to thermos bottles and held approximately 30,000 gallons of active storage (inner tank) and 30,000 gallons of passive storage in the outer lining of each tank. Overall, the tanks have the capacity of 25,000 KWHs of energy storage at a 100° F. water temperature change.

Gaining ownership of the tanks, removing outer equipment and platforms, and obtaining a carrier to transport the tanks to the college was difficult, but they eventually were placed in a partially excavated site near the campus heating and cooling plant.

Special Problems

Most problems occasioned by the energy management system were minor. The mechanical shield drives on the electric boilers caused some difficulty. The computer operating the HVAC system made very quick assessments of impending high (and expensive) demand, but the shield drives could not respond quickly enough. As a result, the computer continued to issue commands that created a cycling or overcompensation effect. The college has replaced these drives with a hydraulic system.

Changes in temperatures and pressures throughout the HVAC system are apparently responsible for a number of pipe leaks, valve failures, etc. In the type of heating system used by the college, losses of water are serious. Considerable time is required to restore the water conductivity that is necessary for the electric boilers to function.

One problem resulted from installation of the heat-storing hot water tanks. The pipes connected with these tanks experience temperature and pressure changes which apparently have caused the pipe material to fail although its specifications indicated that it should not. Repeated failures of this pipe caused the loss of water and energy and have produced improper heat levels in college spaces. The manufacturer of the pipe, the design engineer, the contractor, and the college subsequently participated in the replacement of the pipe with a much higher-quality product.

The need to experiment in some cases also has created a few problems. For example, the lowering of hot water temperatures in the HVAC system has been accomplished gradually to cause unforeseen problems to surface one at a time. A problem of insufficient hot water in the showers occurred but was later found to be related only to an insensitive automatic mixing valve. This valve was bypassed, as it was no longer necessary with the lower temperatures, and the water temperature reductions resumed.

Another minor problem is that college staff have occasionally neglected to plan for unusual building use patterns. As buildings are no longer heated all night or on Saturdays and Sundays, advance warning is needed for plant operators to bypass the preset HVAC schedule for a building that is in use at an atypical time.

Relatively few problems have been experienced in regard to building or room environments. In some cases, the remodeling or change in use of a zone within a building has created a situation that the existing mechanical system cannot handle. With the entire HVAC system much more finely tuned, these problem areas have become more noticeable and will probably require remodeling and redesign of the air handling system for the area.

Butler University
Indianapolis, IN
Enrollment: 4,117

Central Control System

Shortly after the university built a new science complex in 1973, two issues concerning energy became apparent: (1) an excess of energy was being used to operate the effective, but complicated, HVAC system and (2) some form of effective energy management had to be applied as a hedge against the rising utility rates.

To handle both problems, the university installed a Honeywell time-shared central control system (BOSS) in the building. Cost of implementation was $42,000. Since the system began in October 1977, both facility needs and the objectives of energy management have been met.

Energy Savings Measurement

To measure the energy savings, Honeywell and Butler University monitored the facilities' energy-consuming system and conducted a year-long before-and-after cost/consumption comparison between 1977 and 1978. The comparison revealed that the central control system reduced electrical consumption by more than 2,000,000 KWH, and fuel consumption by more than 62,000 therms. This was accomplished by the following techniques:

HVAC equipment programming
Outdoor air control
Damper optimization on ventilation
Optimized start/stop of equipment
Night setback

Cost Analysis

When the system was installed, it was anticipated that the first year's savings would approach $59,000 with a net breakeven point in 10 months. However, after adjusting for seasonal variations in weather, cost of utilities, etc., the actual first year savings amounted to $76,000. A five-year, long-term view of the project indicates at least $260,000 in savings on energy alone, and even more by tying more buildings into the system and including the manpower and maintenance savings. If most of the campus facilities are eventually connected to the Delta 1000 unit it may be advantageous then for the university to purchase a central processing unit and staff and monitor it rather than lease this service.

It is felt that the BOSS system is most advantageous when applied to a highly mechanical facility where the air is heated and cooled and fans are utilized, since the greatest savings in energy is electrical.

The University of Texas Health Science Center
Dallas, TX
Enrollment: 1,240

Co-Generation

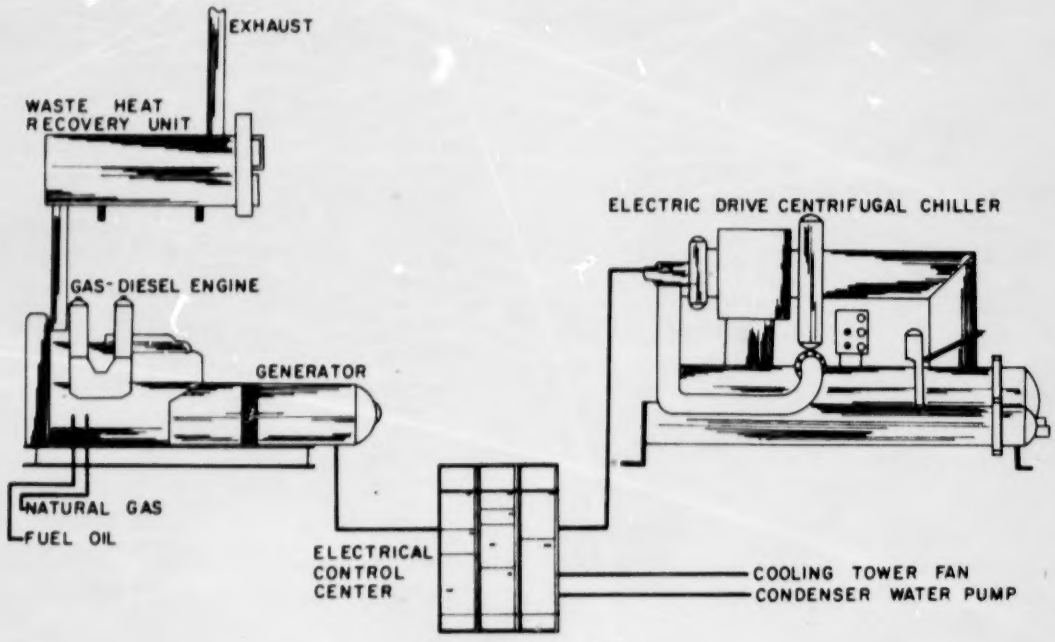
The campus of this university health science center is served by a privately owned thermal energy plant. The initial plant, built in 1972, has an installed capacity of 7,000 tons of refrigeration equipment and 240,000 lbs. per hour of steam generating equipment. The refrigeration equipment consists of two steam-turbine-driven compressors, rated at 3,000 tons each, and a 1,000-ton absorption unit. Chilled water and condenser water pumps are also driven by steam turbines with the back pressure from the turbines supplying energy to the absorption unit and the deaerator.

Study of Campus Cooling Load Profile

In early 1975, the decision was made to expand the chilled water capacity of the plant in order to meet the requirements of new buildings which were then being planned or under construction. The cooling load profile of the campus was studied with a view to (1) selecting the optimum-size chiller(s) that would best fit the profile, and (2) selecting the compressor drive that would use the least fuel per ton-hour. Four systems were studied:

1. Steam turbine drive.
2. Electric motors (purchased electricity).
3. Dual fuel engine (directly coupled).
4. Dual fuel engine with waste heat recovery (directly coupled).

The study recommended installation of one 4,000-ton unit with direct drive from a dual fuel engine (natural gas with No. 2 oil pilot) and a waste heat boiler with economizer. This unit, with its associated chiller, was to serve as the base load unit with the steam from the waste heat boiler discharging into the existing high pressure steam header. While this system was expensive on a first cost basis, the off-setting savings in fuel consumption made the system very attractive.



Thermal Energy Plant

Design, Installation Details

Certain engineering problems and a more comprehensive campus cooling load profile caused a change in the recommendation of the thermal energy contractor. The installed system consists of the engine/generator set electrically coupled to two 2,500-ton centrifugal compressors, two chilled water pumps, and three condenser water pumps. The selected engine is a V-16 unit rated at 6,000 BHP when operating at 400 RPM and 185 BMEP. The generator is an 18-pole unit with brushless exciter rated at 4,475 KW. The new portion can operate independently of the original portion, which is still served by electrical power from the local utility company. Since the plant serves a medical complex, this diversification is a desirable enhancement of the plant's reliability.

Justification, Cost Analysis

The study indicated that while this system was the most expensive in terms of investment, it represented the lowest cost when total owning and operating costs were included. More important, the system was the best of all those studied in overall thermal efficiency. It should be noted that the analysis of the electric motor drive (purchased power) included losses at the generating plant and in the electrical distribution system when comparisons of fuel consumption were made. According to the study, the natural gas consumption of the systems under consideration are as follows:

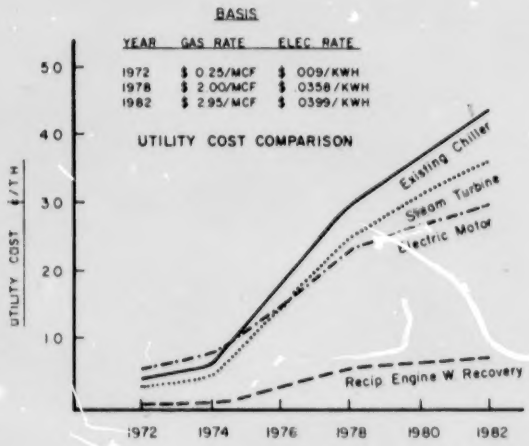
Existing Turbines	18.0 cu. ft./ton-hr.
New Turbines	12.6 cu. ft./ton-hr.
*Electric Motor	6.0 cu. ft./ton-hr.
Engine	5.5 cu. ft./ton-hr.
**Engine with Recovery	2.2 cu. ft./ton-hr.

*Based on 9 cu. ft./KWH at power plant.
**Includes credit for the steam from the waste heat boiler (this now does not have to be generated by the existing boilers).

The study indicated that for the recommended chiller size, the following cost could be expected:

Prime Mover	4,000-Ton Addition
Steam Turbine	$3,925,000 ($981 per ton)
Electric Motor	$3,956,000 ($989 per ton)
Natural Gas Engine	$4,483,000 ($1,120 per ton)
Natural Gas Engine W/Heat Recovery	$4,765,000 ($1,191 per ton)

It is anticipated that the payback period on the new system will be three to four years. It is difficult to determine the exact payback period because of interacting elements, such as other energy conservation measures on campus and their effect on total base load ton-hours. A major factor in the savings is the campus' year-round demand for steam, which is greater than the capacity of the waste heat boiler when the engine is operating at full load. Further, it can be seen from the graph below that the installed system is relatively insensitive to changes in fuel costs. This is explained by the fact that the amount of fuel used to produce one ton-hour of cooling is significantly less than any of the other systems that were studied, and therefore a change in fuel costs has less impact.



In August 1978, a new rate schedule went into effect. Billings were calculated under the old rates and, when compared with actual billings under the new rates, the impact of the more thermal-efficient system is evident:

	Billing Under Old Rates	Billing Under New Rates
August	$435,283.75	$406,911.61
September	$406,926.06	$382,898.47

Under the new rates, approximately three times as much capital investment is being recovered as under the old rates.

Funding, Operation

All work, including preparation of the working drawings, was the responsibility of the thermal energy contractor. The plant is operated by the thermal energy contractor, who also provided funding for the project. He will recover funds through a fixed monthly charge

and a commodity charge. The fixed monthly charge recovers, during the term of the contract, all fixed costs associated with the construction, operation, and maintenance of the plant, such as cost of capital, insurance, overhead, profit, taxes, and labor; that is, all costs not associated with actual production of chilled water and steam. The commodity charge recovers the variable cost which is directly associated with production such as fuel, electricity, and water and water treatment. It should be noted that the contractor gives credit for all steam generated by the waste-heat boiler.

Special Problems

The most significant problem developed because engine and refrigeration machine manufacturers are hesitant to directly couple the engine and compressor, due to the possibility of reverse torque. As a result, there was a change from direct coupling to electrical coupling of the engine and chillers. Problems also were encountered with respect to assigning responsibility for the drive train, including the gear box.

Operating Details

The heavy cooling load on this campus is due principally to requirements for use of 100 percent outside air. The cooling load tracks the outside air temperature closely. The new system can be made to react to this varying condition in a unique manner. The controls are set in such a way that there are three steps in capacity control of the chillers. First, as the load begins to fall, the generator reduces the frequency by a maximum of 10 percent, to 54 Hz. Second, the compressor inlet vanes begin to modulate, closing to a point just before surging occurs. Then, third, the hot gas by-pass begins to open. It is hoped that the last stage can be avoided by eliminating one chiller. (Frequency reduction applies to the pumps also.)

University of Pittsburgh
Pittsburgh, PA
Enrollment: 29,444

Economizer System

Salk Hall is a four-story building constructed in 1967, with an area of 107,000 gross square feet. The top three floors are used for dental patient care. The first floor contains one large classroom, a stockroom, and a locker room. The building is heated by central steam and cooled by a 350-horsepower chiller through a dual-duct, constant volume mixing box system, and uses 3,800,000 KWH per year. The three air systems move 110,000 CFM, but are only capable of introducing 20,000 CFM of outside air, which is not sufficient to handle the interior cooling load during the winter. Therefore the chiller and all auxiliaries are in operation twelve months a year.

Economizer System Introduced

An economizer system is being installed to utilize free cooling from outside air during the winter. This involves the following alterations to the building and air systems:

1. Increasing the size of the outside air intake from 40 square feet to 110 square feet.

2. Increasing the capacity of the outside air ducts to each air handler by installing new ducts parallel to the existing ducts.

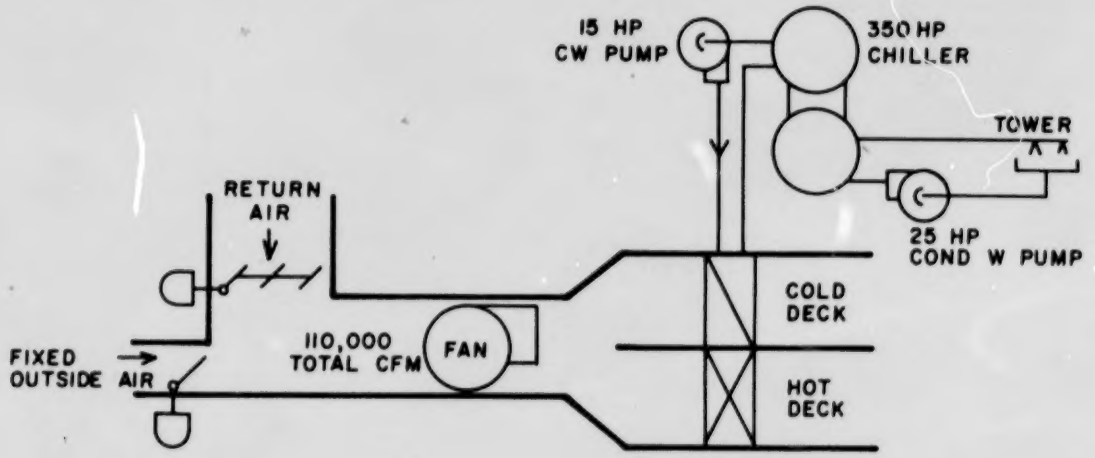
3. Construction of a relief air chase from the second floor through the roof.

4. Minor revisions to the existing controls to provide a temperature economizer for the three air handlers.

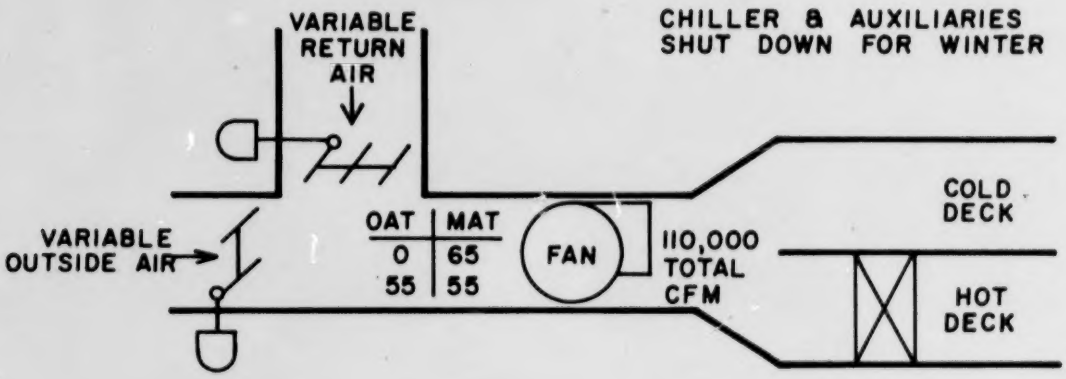
When the installation of the economizer is complete, the chiller and auxiliaries will be shut down from approximately mid-October until May.

Justification

This project was justified by a simple estimate of the cost of running the chiller and auxiliaries during the winter, and the assumption that the economizer would save this amount. It was also assumed that the perimeter fin tube would eliminate the transmission heating load. Since each floor is a large open area with a uniform cooling load, the hot decks could be shut down in the winter and



ORIGINAL SYSTEM CONFIGURATION
WINTER OPERATION



REVISED SYSTEM CONFIGURATION
WINTER OPERATION

there would not be a charge against the economizer for steam used for reheat in the hot deck.

Implementation, Funding

All load and energy use measurements and the economic justification of this energy conservation alternative were performed in-house. Design of specified system modifications was provided by Meucci Engineering, Inc., and construction was performed by McKamish Metals, Inc. Cost analysis indicated a payback period of thirteen months for this project, which was totally funded by the university.

Although the system conversion is not yet complete, the successful operation of existing temperature economizers in other campus buildings assures that the system will operate as expected and produce the savings which were calculated. Project cost was $15,500 for design and construction and will save an estimated $14,600 annually.

Thomas Jefferson University
Philadelphia, PA
Enrollment: 1,720

Chiller Condenser Automatic Brush Cleaning System

A Wa[illegible] Service of America system of in-line automatic brush cleaning of chiller condensers was installed on each of three of the university's American-Standard 800-ton chillers.

Justification

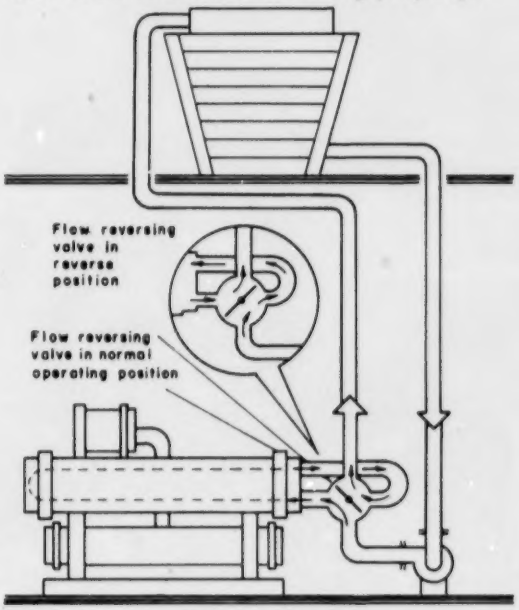
Permission was granted by the Department of Physical Plant in early 1976 for an engineering study to be made by a mechanical contractor, to determine the cost effectiveness of the above installation in Jefferson Alumni Hall. This facility houses the university commons and the basic sciences functions of the university medical college, and has a large air conditioning system totaling 2,400 tons. This analysis indicated that the reduction in fouling of the tubes by 19 percent, resulting from installation, would produce annual savings of $17,600 in electrical energy costs. This saving was calculated using the electrical energy cost at the time — $.0289 KWH. The equipment and all installation costs were estimated to not exceed $47,000. On this basis, the payback period would be two and one-half years, and it was decided that such an installation was justified.

Design, Implementation

A major mechanical contractor, Williard, Inc., completed the installation prior to the 1977 cooling season. The first step was thorough cleaning of the condenser tubes. Then they were carefully measured to be sure that the brushes to be installed were the correct size; if the brushes should be too small, they would not clean properly; if too large, they might become jammed in a tube. The necessary piping changes came next, in order to accommodate the flow-reversing valve. Simultaneously, the brushes and the baskets were placed in each condenser tube. Each machine condenser has 960 brushes and, hence, 1,920 nylon baskets. Each basket is pressed into its condenser tube end and cemented with epoxy.

Operation

A mechanically linked operation counter, mounted at eye level rather than on the overhead valve, has been added for taking regular readings to be sure the flow reversing valve is functioning. Since operation is completely automatic, it requires only monitoring of equipment to be sure it is functioning properly.



Flow diagram depicts flow reversing valve operation

Cost Analysis

The project was funded by the operating budget of the Department of Physical Plant. The energy consumption of the machines during the summer of 1977 was compared to that of 1976 and showed an approximate reduction in electrical energy consumption of 20 percent. Based on 1978 electrical rates ($.0369 per KWH), this is a saving of $25,670. Since the original installation cost was $45,284, the payback period is less than two years. A continued rate of about $25,000 annual savings is expected.

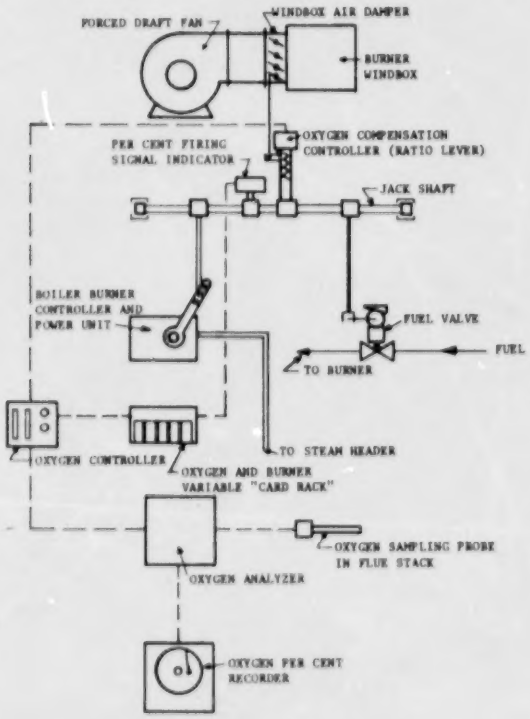
The University of Nebraska Medical Center
Omaha, NE
Enrollment: 1,748

Boiler Instrumentation and Heat Exchangers

Central steam generating facilities at the medical center consist of four water-tube boilers with a combined generating capacity of 240,000 pounds per hour of steam (two boilers at 50,000 pounds per hour and two at 70,000 pounds per hour). The burners use natural gas (when available) or No. 5 or light No. 6 fuel oil.

Project Description

Each boiler burner is being equipped with a zirconium oxide oxygen analyzer which samples, analyzes, and records the percentage of oxygen in the flue gas; this will be used to determine the percentage of excess air being introduced by the burners' forced draft fans. A device is added to the burner jackshaft and linkage to accomplish this without upsetting the basic combustion controls.



Boiler Instrumentation

Electronic controllers, which are preset to manipulate a damper on the boiler burner, are activated by a signal from the oxygen analyzer so that the percentage of excess air can be kept at a minimum safe level for optimum combustion. It is expected that excess air will be reduced to between 10 and 6 percent. This automatic corrective action, or "oxygen trim," increases burner efficiency and reduces fuel consumption. Devices such as this have been used on larger boilers (more than 100,000 pounds per hour) but only recently have they been successfully employed on smaller units.

In addition to the above modifications, the medical center is installing piping, sensing probes, and heat exchangers. Upper drum continuous blowdown liquid will be transported through heat exchangers that will preheat the make-up water required for the blowdown and other make-up water. The blowdown water will be cooled from 355°F. to 140°F. before being discharged into a waste pipe system.

Funding, Cost Analysis

The project is being financed from funds allocated to up-grade existing facilities that have a definite payback as a result of operating savings. Savings of fuel by the instrumentation and controls are estimated at $20,000 to $21,000 annually, and the heat exchanger system is expected to result in annual savings of $4,800 to $5,000. Cost of implementation is expected to be $105,460. Payback for the entire project is conservatively estimated at 4.25 to 4.06 years. The equipment life expectancy is ten to fifteen years, not including normal wear and replacement items.

Installation, Evaluation

Installation is being accomplished by a local mechanical contractor and equipment supplier; university employees are not involved. Evaluation indicated that the only flue gas oxygen analyzer that would respond properly and create the expected savings is the zirconium oxide type.

University of North Dakota
Grand Forks, ND
Enrollment: 8,858

Bearing-Cooling Water Retrofit

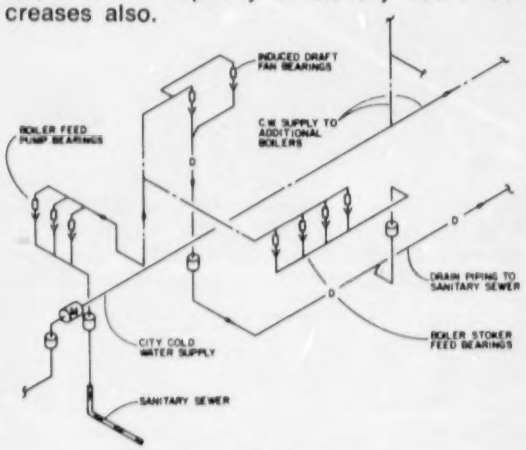
The university's plant services department initiated this project in an effort to reduce operating costs, conserve energy, and eliminate waste. Common to most coal boiler plants is the need to provide constant cooling to bearings for the boiler feed pumps, stokers, and induced draft fans. The typical means of cooling is to provide city water to the bearings and then dump the water into the sanitary sewer system. For the university boiler plant, this waste of water amounted to an excess of twelve million gallons per year. The recently completed retrofit project reduces the quantity of waste water by approximately 75 percent.

Project Description

The basic concept of the system is to recapture and re-use the waste heat in the bearing-cooling water systems. This permits recirculation and reduces water waste. The heart of the system is an external dry cooler that utilizes the cooler winter air of the northern area to provide natural cooling.

Multiple system pumps for bearing cooling are used in conjunction with the air-to-glycol heat exchanger or dry cooler (See schematics). The bearing cooling water is pumped to the various bearings, returned by gravity through a heat exchanger to a surge tank, and recycled. The cooling pump circuit utilizes a glycol solution which is pumped through the heat exchanger and dry cooler. The temperature in the surge tank is maintained by cycling the glycol pump and an automatic staging control which cycles the fans at the dry cooler to provide necessary cooling. When the outdoor ambient temperature rises to a point (75°F±) where cooling cannot be provided, an outdoor sensor automatically shuts off the glycol pump and dry cooler. Tank temperature is maintained thereafter by bleeding cold city water into the tank through a modulating, motorized valve controlled by a temperature sensor within the tank. Excess water overflows to drain and is wasted.

It should be noted that the design parameters of the system are such that the cooling system capacity increases as the need for bearing cooling also increases. As the outdoor temperature drops, the system demand increases and the boilers generate more heat, thus the bearings need more cooling. In turn, a larger temperature difference exists between the glycol and the outdoor air; thus the capacity of the dry cooler increases also.



Piping Schematic Prior to Retrofit

Although mechanical refrigeration cooling systems were considered, the costs proved to be prohibitive. Because the design parameters work to the total advantage of the system requirements, the dry cooler approach provides the necessary cooling for 75 percent of the requirements. Also, during the period of time that the dry cooler is inoperative, steam demand is at a minimum. Field testing has also shown that, due to the minimum requirements, the tank temperature can be increased substantially and still provide adequate cooling to the bearings. This approach to raising tank temperature minimizes the requirements for excess city cold water.

Special System Considerations

Although the basic concept and design requirements of the retrofit project are fairly straightforward, a special consideration for the project is "failsafe controls." It is critical that cooling water flows to the bearings *continuously*. Due to the high temperatures

in the boilers, extensive damage would occur in a short time if the flow were interrupted. Therefore, the system has to be failsafe. Several safety back-up systems with automatic controls, alarms, and indicators were required. These are as follows:

1. In the event of pump failure, both a "No Flow" sensor light at the monitoring panel and an alarm are activated. Simultaneously, an emergency valve opens to provide city water flow to the bearings. In addition, an emergency flow indicator lights at the monitoring panel to advise the operator that flow exists.
2. A high temperature sensor activates an alarm if the water temperature to the bearings exceeds the setpoint. The operator can then open manual by-pass valves to insure adequate cooling until the problem is corrected.
3. In the event of a power failure, all emergency valves are spring-returned to open positions to allow immediate city water flow to bearings.
4. The central console continuously monitors outdoor temperatures, tank temperature, heat exchanger temperatures, and dry cooler temperatures. All light indicators, pump run, etc., are contained at the panel for ease of monitoring by the operator.

Cost Analysis

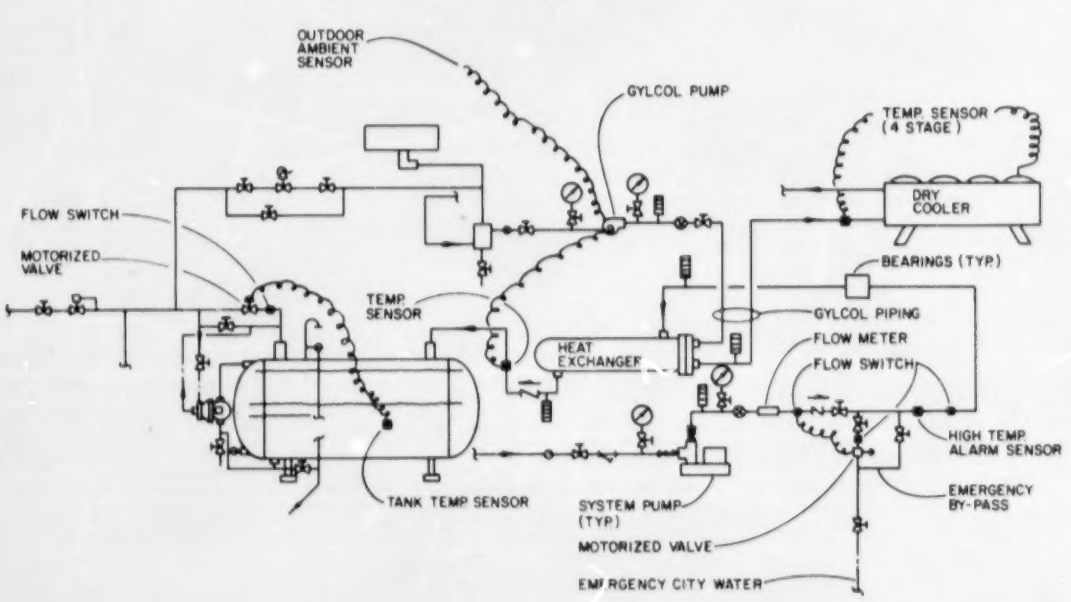
The entire project was funded from appropriate plant improvement funds. It was designed to use standard materials for piping, equipment, and controls. The project was advertised for competitive bidding and the contract cost was $53,300; local contractors completed the work.

As previously noted, the recycling of bearing-cooling water should reduce the wasted water amount by an expected 75 percent. Original usage figures (twelve million gallons per year) were computed through actual field measurements and by consulting previous records relative to hours of operation and water billings. The anticipated savings, nine million gallons of water per year, amounts to approximately $8,000 annually.

Calculations based on contract amount and expected savings indicate approximately six and one-half years' payback or an estimated $117,000 savings over twenty years. These figures are based on current costs and usage. Due to campus expansion and current installation of another boiler, usage is expected to increase. The anticipated payback time is expected to be less than indicated originally.

This system concept may have application in other areas that have cooling requirements and a large number of heating degree days. For example, one major application could be as a supplement to mechanical cooling for ice-making equipment for winter sports arenas. Other applications are large walk-in coolers and freezers in cafeterias and bakeries.

Retrofit Piping Schematic



University of Michigan
Ann Arbor, MI
Enrollment: 36,863

Boiler Efficiency Improvement Program

Boiler Water Treatment Program (Phase I)

Condensate returning from approximately seven miles of tunnels into the power plant contained excess iron and copper contaminants which created scale build-up on the boiler tubes, reducing firing efficiency and causing numerous instances of tubes bursting or bulging. Since the process steam is used in hospital and medical centers, amines can not be used to reduce the contaminants.

Steps taken to eliminate boiler scale included:

1. Adding SCA, a mild chelate system, to improve chemical treatment to the boilers.
2. Improving operation of the make-up demineralizer system partly by adding a caustic heater to the demineralizers.
3. Adding boiler water and steam analysis and monitoring equipment to maintain close control of both systems.

Steps taken to improve the condensate return system included:

1. Adding weirs in the hot wells upstream of the condensate pump suction to eliminate most of the iron and copper particulates.
2. Adding a DeLaval mechanical separator upstream of the condensate polishers. These two changes removed more than 90 percent of the particulates, greatly improving the efficiency of the polishers in regard to finer particulates and the iron and copper material in solution.
3. Installing an automatically controlled bypass system around the polishers to maintain optimum flow velocity through the polishers at low loads.
4. Operating the condensate polisher more efficiently by improving the distribution system and air system and by adding metal treatment to the resins.
5. Hiring a qualified chemist to oversee the water treatment program — the single best investment made.

Improving Boiler Efficiencies (Phase II)

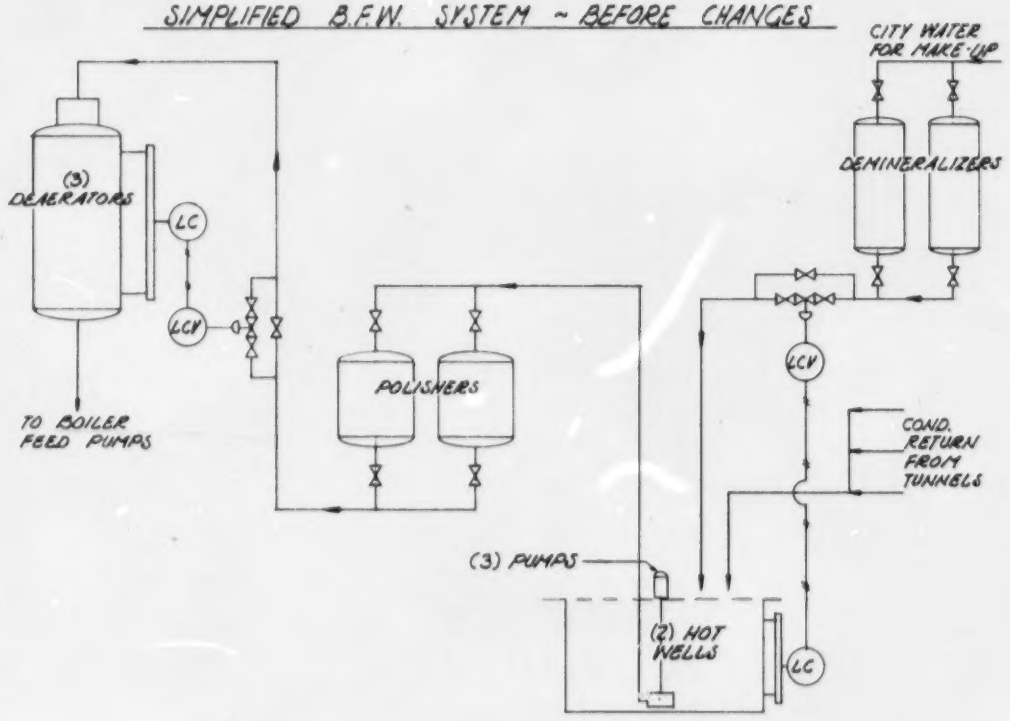
An oxygen analyzer was purchased and installed to constantly monitor boiler firing efficiency. Since excess oxygen literally blows "heat up the stack," this addition made a significant improvement in boiler efficiency.

Results

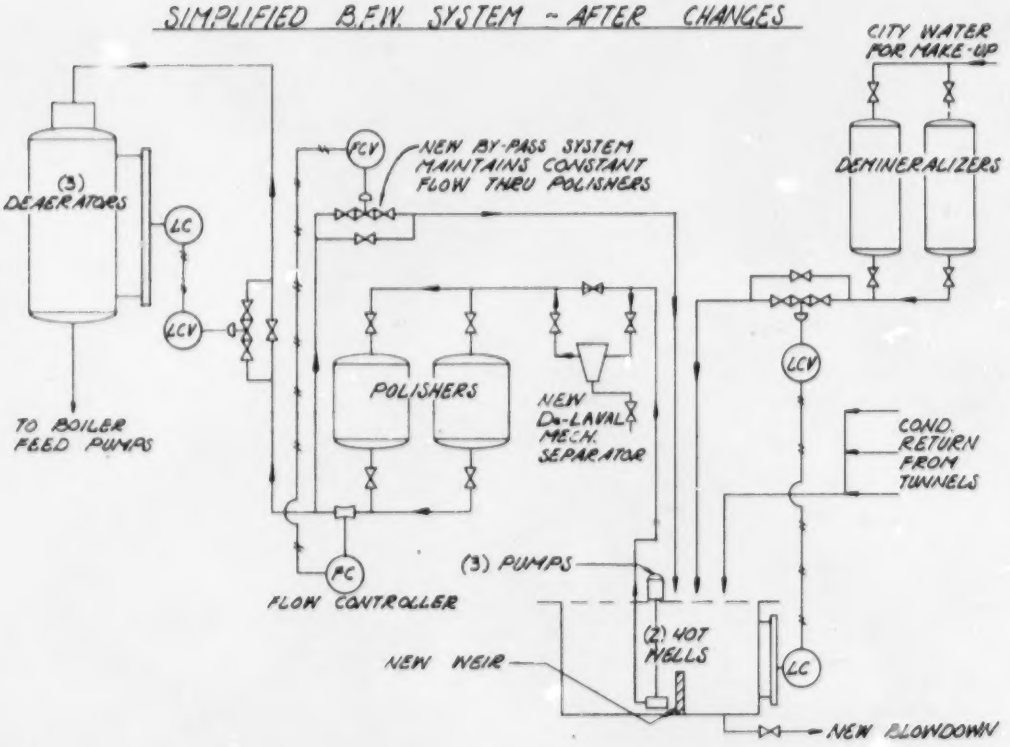
1. The oxygen analyzer reduced fuel cost by $40,000 annually.
2. Condensate and water treatment programs, to keep boiler heat transfer surfaces clean and efficient, further reduced fuel costs by $27,000 per 1 percent improvement in each boiler annually.
3. Savings realized from items Nos. 1 and 2 above, in addition to improved reliability and reduced downtime and maintenance, came to more than $200,000 in one year.

(See diagram opposite)

SIMPLIFIED B.F.W. SYSTEM ~ BEFORE CHANGES



SIMPLIFIED B.F.W. SYSTEM ~ AFTER CHANGES



Berklee College of Music
Boston, MA
Enrollment: 2,384

Open Chilled-Water Loops

This program involved a special, patented strainer system, a special chemical treatment program, and the installation of automatic valves which allow the closed chilled and open condenser water loops to be interconnected without contamination or corrosion problems in one continuous open water loop. When this occurs, the cold condenser (tower) water is pumped directly through the cooling coils in various air handlers. The valves, various pumps, and the steam absorption machine are controlled by wet bulb controllers (or manualiy), which determine when the tower water will not be sufficiently cold to fill cooling needs. When this happens, valves close the single loop into the two original loops, and the steam absorption machine is activated and supplies the necessary chilled water. The strainer is necessary to clean the tower water before it reaches the cooling coils; it is not used when the absorber is running.

Project Description

The project was implemented by an outside firm, and is based on the premise that, at temperatures below design, cooling towers can reduce circulating water temperature to a point that approaches prevailing outside wet bulb temperature. As a result, condenser water temperature can often be reduced sufficiently to meet cooling needs without operating refrigeration machines.

The system installed was *Strainercycle*, a patented, proprietary energy-conserving system produced by Thermocycle, Inc., of New York. *Strainercycle* provides cooling, under specific climatic conditions, by injecting condenser water through the normally closed primary and secondary chilled-water circuits. Protection from silt and scale deposition and corrosion is provided by use of an automatic self-cleaning strainer and a specific water treatment program. Larger particles (those greater than .005 inches) picked up through the cooling tower or present in the system are removed by a strainer prior to introduction of the water to the normally closed systems.

A polymer-based, broad-spectrum water treatment program inhibits scale deposition and keeps particles in suspension until they can be removed automatically by tower bleed-off and strainer backwash. Compatability of systems is maintained by utilizing the same water treatment program in all systems. Water treatment is applied in direct proportion to the make-up water and dissolved solids are monitored and controlled by an automatic bleed. Maximum protection with minimum waste is thereby achieved. The installation of corrosion coupons permits monitoring of corrosion-inhibiting efficiency of the treatment program, allowing corrective measures to be taken before the system is adversely affected.

Savings Achieved

Payback for the initial twelve months of operation was $10,000 greater than the $34,000 cost of installation. In addition, savings in steam "M" pounds are indicated in the table below:

	"M" Pounds			"M" Pounds		Savings
Mar. 1976	— 3,600		Mar. 1977	— 2,500	=	1,100
Apr. 1976	— 3,100		Apr. 1977	— 1,700	=	1,400
May 1976	— 2,900		May 1977	— 1,250	=	1,650
Oct. 1976	— 2,400		Oct. 1977	— 1,480	=	920
Nov. 1976	— 4,100		Nov. 1977	— 1,350	=	2,750
Dec. 1976	— 3,200		Dec. 1977	— 2,450	=	750
Jan. 1977	— 3,280		Jan. 1978	— 2,230	=	1,050
Feb. 1977	— 3,700		Feb. 1978	— 3,100	=	600
			Total savings in "M" pounds		=	10,220

1. Strainer operation start-up March 2, 1977.
2. November 1976 abnormally high due to other mechanical problems.
3. $45,607.59 savings for the months the unit was in operation.

41

Projects in Brief

Projects in Brief

The following projects have been listed under the same general categories as the more detailed projects that appear in the previous section. A wide variety of methods of energy management is indicated in these brief descriptions; for more information, refer to the "Index of Institutions," page 55, for addresses and persons to contact.

Building Envelope

Storm Windows; Other Window Insulation

Augustana College installed aluminum storm windows on 280 windows of a forty-one-year-old women's residence hall that comprises 66,989 gross square feet, at a cost of *$6,426*. Savings have not yet been determined, due to recent implementation.

The College of St. Catherine installed storm windows on two floors of a twenty-two-year-old facility comprising 76,431 gross square feet and serving three purposes — those of residence hall, student union, and place for instruction. Cost to implement the installation was *$19,000*, with estimated annual savings of *$1,200*. In addition, polyethylene sheeting was installed inside all the windows of a fifty-one-year-old science hall comprising 71,600 gross square feet. Cost of implementation was *$703.63;* air infiltration tests provided an estimate of *$1,750* to *$2,100* in annual savings.

The University of Louisville applied 4 mill polyethylene sheeting to the glassed-in area of a "climatorium," comprising 2,000 gross square feet, in which plants and algae are cultivated for use in biology classes. Cost to implement was *$20* with annual savings of *$600*.

Insulation (Walls and Attic)

Augustana College had insulation blown in under an attic floor and in other areas of two buildings; a four-story, ninety-five-year-old stone building comprising 42,401 gross square feet, in use as classrooms and offices, at a cost of *$7,650;* and one wing of a three-story women's residence hall, covering 10,547 gross square feet, at a cost of *$5,273.50*. Savings have not yet been determined, due to recent implementation.

The College of St. Catherine insulated the attics of two fifty-three-year-old residence halls; one, comprising 110,500 gross square feet, at a cost of *$3,250*, and one of 25,620 gross square feet at a cost of *$1,475*. Annual savings are estimated at *$2,500* and *$1,800*, respectively; payback will be between one and two years.

Princeton University installed attic insulation in 22 residence halls, 8 administrative buildings, 230 married student homes, and 6 research buildings at a cost of *$71,700*. Savings are estimated at *$15,000* annually, a payback of four to five years.

Syracuse University installed attic insulation in a fifty-year-old residential frame building, comprising 7,660 gross square feet, at a cost of *$2,900*. Annual savings are expected to be *$1,300*, a payback of 2.18 years.

The University of Iowa insulated a number of its older campus buildings with blown cellulose insulation. Cost to implement the project was *$39,509* with estimated annual savings of from *$10,000* to *$15,000*, a payback of three to four years.

Miscellaneous

Kalamazoo Valley Community College installed five storm windows and door sweeps on thirty doors, and implemented threshold repair and caulking at a cost of *$900*. Savings have not yet been determined due to recent implementation.

Electrical Systems

Disconnects and Ballast Changes

Clark County Community College disconnected ballasts in 25 percent of the lighting fixtures in all areas of its one campus building, which comprises 194,530 gross square feet. This included classrooms, laboratories, shops, and administration areas. Cost to implement, together with other energy conservation measures, was *$7,500*, with estimated savings (combined with other conservation results) of *$30,000*.

Florida Atlantic University removed 1,520 lamps and disconnected 760 ballasts (four 40 watt fluorescent lamps taken from each eight-lamp fixture and two ballasts disconnected from each) in a fourteen-year-old library building comprising 73,091 gross square feet. Because of redistribution of light, using new lenses, no significant loss of foot-candles of light on book stacks was experienced. Disconnected ballasts were left in fixtures for future replacement. Cost to implement was *$9,882.86*, with annual savings of *$12,981.36*.

Kalamazoo Valley Community College disconnected approximately half the fluorescent lamps in facilities constructed in 1968-1970 (comprising 288,372 gross square feet) at a cost of *$600*, with annual savings of *$7,000*.

The Massachusetts Institute of Technology replaces all its fluorescent tubes as a group every three years, at which time the fixtures are cleaned. Illuminated areas are surveyed at that time to determine lamp deployment to meet required illumination levels and eliminate unnecessary lighting. Cost to implement is 4 cents per 100 square feet, with savings in lighting ranging from 5 to 60 percent.

Occidental College removed lamp bulbs from fixtures throughout the campus, chiefly in hallways, areas of the library, and various offices. Cost of implementation was *$1,000* with estimated annual savings of *$20,000*.

San Francisco State University removed tubes on fluorescent lighting fixtures in two science buildings, which comprise a total of 326,500 gross square feet, reducing lighting levels from 140 to 60/70 foot candles. Cost of implementation was *$600*, with estimated annual savings of *$25,000*.

Southern Utah State College removed fluorescent tubes and disconnected ballasts in its facilities to bring lighting levels down to Utah State Building Board specifications. Approximately *$17,534* in savings was anticipated for the first year.

Syracuse University instituted a lighting reduction program that affected five buildings and involved total deactivation of some fixtures in corridors, the disconnecting of one out of three ballasts in certain multiple fixtures, and the replacement of some incandescent lamps with fluorescent fixtures. Reduction of annual electricity consumption ranged from 5.5 percent to 10 percent.

Lamp Conversion

The College of St. Catherine replaced 90 percent of its incandescent campus security lamps (300 to 500 watts each), with 175-watt holophane metal halide fixtures at a cost of *$5,046*. Savings are estimated at *$1,752* annually.

Eastern Michigan University converted 51 incandescent bulbs (750 watts each) to 450 self-ballasting mercury vapor lamps in a fourteen-year-old physical education building comprising 95,349 gross square feet. Cost to implement was *$1,224* with annual savings of *$2,904*.

Marquette University replaced standard cool white fluorescent lamps with GE Watt-Miser II lamps at a cost of *$4,200* over a year, with savings of *$26,400* (figured over the lifetime of bulbs replaced in a given year). In addition, the university converted its perimeter security and parking lot lighting from incandescent to mercury vapor, high pressure sodium, and low pressure sodium lamps. In addition to saving energy, this conversion caused additional areas to be illuminated and lighting levels were increased by 200 to 300 percent. Cost to implement was *$2,940* with annual savings of *$730*.

The Massachusetts Institute of Technology converted the ceiling lighting of a 14-year-old building (comprising 94,000 gross square feet and used for library and offices) from an inefficient fluorescent system to a new fluorescent system using suitable luminaires that provide required light levels with a significant reduction in lighting power and, hence, in air conditioning load. Power levels previously were 63 KW; the new levels are 18.5 KW. Cost to implement was *$47,284*, with annual savings of *$11,980*.

Northern Michigan University replaced the 1000 watt incandescent lighting system in its twenty-year-old fieldhouse and gymnasium (92,606 gross square feet) with 400 watt metal halide and mercury vapor systems. Cost to

implement was *$43,000* with savings estimated at *$10,000* to *$12,000* annually.

Occidental College replaced 1500-watt incandescent light fixtures in its gymnasium — a fifty-five-year-old building comprising 14,588 gross square feet — with 400-watt metal halide light fixtures. Fifteen units were involved, with a cost of *$3,000* to implement the project and estimated annual savings of *$3,000*. In addition, the college replaced some exterior lighting and incandescent light fixtures in many hallways with fewer fluorescent or mercury vapor fixtures. Cost to implement was *$3,000* with estimated annual savings of *$10,000*.

Princeton University replaced 492 40 watt fluorescent lamps (out of a total of 1,252) with 35 watt units in a forty-eight-year-old building comprising 33,840 square feet. Cost to implement was *$1,400*, with estimated annual savings of *$400*.

The University of Connecticut converted its outdoor lighting to high-pressure sodium lamps, doubling illumination levels across campus. Cost of engineering study was *$300*, with annual savings of approximately *$7,000*.

The University of Prince Edward Island converted four-tube fixtures to two-tube fixtures and changed the tubes from warm white to cool white without any appreciable drop in light levels. Cost to implement was approximately *$600* with annual savings estimated at about *$40,000*.

The University of Wisconsin at Superior replaced eighty 1500 watt incandescent fixtures with twenty-four 1000 watt high-pressure sodium fixtures in its recreational field and stadium. Cost to implement was *$8,790*, with estimated annual savings of *$1,334*.

Phantom Tubes

Cleveland State University installed phantom tubes and decreased its incandescent lamps from 150 watts to 75 watts in its five-year-old physical education building, which comprises 201,216 gross square feet. Cost to implement was *$1,661* with annual savings of *$5,644*. In addition, the university installed phantom tubes in a four-year-old building used for offices and the student union, comprising 198,219 gross square feet, and replaced 40 watt tubes with 35 watt tubes. Cost to implement was *$2,755* with annual savings of *$15,782*. Phantom tubes and 35-watt tubes were also installed in an eight-year-old office and library building comprising 481,557 gross square feet, at a cost of *$26,221* with annual savings of *$57,389*.

The Maine Maritime Academy lowered light levels from 140 foot candles to about 60 foot candles in many classrooms and offices of a hundred-year-old building comprising 42,000 gross square feet. The change was accomplished by removing bulbs and ballasts and by using "wattsaver" bulbs and "phantom" tubes in the remaining fixtures. All two-lamp hall fixtures were modified by the installation of one phantom tube in each. Cost to implement was *$1,150*, with estimated annual savings of *$650*.

Time Clocks

Clark County Community College placed automatic time clocks on lamps in the hallway, common areas, and parking lots of its campus building at a cost of *$7,500*, together with other conservation measures, with estimated annual savings (together with other conservation results) of *$30,000*.

The Massachusetts Institute of Technology installed one-hour twist timers in some classrooms of various buildings at a cost of *$15* per switch, with estimated annual savings of *$18* per switch.

Occidental College installed photo-electric cells on security lighting systems and on certain lighting systems in hallways, thus providing illumination only when required. In some cases, these were installed in series with time clocks. The cost to implement was *$1,000*, with estimated annual savings of *$4,000*. In addition, the college installed low voltage light control switches in individual offices of a ten-year-old administration building, comprising 37,943 gross square feet, at a cost of *$1,500*, and in various areas of its eight-year-old library, comprising 101,834 gross square feet, at a cost of *$750*. Annual savings are estimated at *$5,000* and *$1,000* respectively.

Capacitor Installation

Marquette University installed power factor correction capacitors at an incoming 13,200-volt primary service location at a cost of *$14,000*, with annual savings of approximately *$12,000*.

The University of Hawaii at Manoa installed a total of 4000 KVARs of capacitors, in five groups, on the 12,470-volt campus distribution system. This raises the power factor from 88 percent to 98 percent and reduces current

by eliminating wattless power. Power transmission losses and power factor penalties are eliminated; line voltage and regulation are improved. Cost to implement was *$50,000*, with annual savings of *$39,000*.

Miscellaneous

The University of Louisville adopted a lighting standard of 50 foot candles for classrooms and offices in new buildings and reduced levels to 50 foot candles in existing buildings; 35 watt fluorescent tubes are being used exclusively. One-hour timers have been installed on classroom lamps and a public awareness drive, using signs, has been implemented. Cost of timers and signs was *$1,000*; estimated savings are *$40,000* to *$50,000* annually.

The University of Pittsburgh turned off approximately one half of all lamps in its twenty-year-old library, comprising 236,040 gross square feet, with resulting annual savings of *$46,250*.

Heating, Ventilating, and Air-Conditioning Systems (HVAC)

Total Building System Conversions

Carleton University altered the mechanical systems in its administration building (comprising 93,200 gross square feet) to prevent, as much as possible, the simultaneous supply of heating and cooling. This included varying the cooling air supply close to the fan end of the system, rather than the terminal end; and reducing control zones from 240 to 4 (one for each face of the building). Use of the supply fan has been reduced so that it normally operates at only about 33 percent of the time and peaks at only 66 percent of its originally designed volume. Cost to implement was *$74,000*, with savings the first year of *$33,500*.

Georgia State University scheduled HVAC equipment for minimum demand and consumption and discontinued operation of dual duct heated and chilled air systems in a ten-year-old classroom and office building comprising 93,000 gross square feet. Cost to implement was *$49,000* with annual savings of *$42,000*. The same procedure was carried out in other facilities as follows: an eight-year-old fine arts building comprising 105,600 gross square feet, at a cost of *$55,000* and annual savings of *$77,000;* a seven-year-old classroom and office building comprising 208,400 gross square feet at a cost of *$109,000* and annual savings of *$153,000;* a four-year-old office building comprising 331,245 gross square feet, at a cost of *$174,000* and annual savings of *$243,000;* a fifteen-year-old student center comprising 119,000 gross square feet, at a cost of *$62,000* and annual savings of *$53,000;* and a five-year-old physical education building comprising 125,250 gross square feet, at a cost of *$66,000* and annual savings of *$92,000*.

Princeton University installed variable volume systems in six buildings comprising 1,042,798 gross square feet. Energy is saved by circulating the minimum required amount of air to provide comfort and by reheating only the absolute minimum air flow. Cost to implement was *$175,465* with estimated annual savings of *$36,650*.

Heat Recovery

Acadia University installed a heat reclaim unit and air recycle controls in the exhaust air systems of its gymnasium and athletic center. The air recycle system controls make-up air on the basis of building occupancy. Cost to implement was *$30,000* with annual savings of *$11,500*.

Marquette University implemented a project to use condensate from the heating system to preheat domestic water for student and food service purposes, rather than dump the hot condensate in the city sewer system as had been done previously. Cost of implementation was *$10,335* with annual savings of *$5,870*.

Temperature Controls, Time Clocks

Clark County Community College installed automatic time clocks on all heating, ventilation, and air conditioning systems in its college building. Cost of implementation, together with other energy conservation measures, was *$7,500*, with annual savings (combined with other conservation results) of *$30,000*.

The College of the Holy Cross installed nine electronic panels (heat timers) in the central power plant, thus dramatically upgrading the temperature control system in nine residence-classroom buildings. Cost of implementation was *$8,785*, with annual savings of more than *$16,000*.

The College of St. Catherine installed Danfoss individual radiator control valves on all the radiators of a fifty-three-year-old administration and residence building comprising 110,500 gross square feet. Cost to implement was *$4,427.50*. It is not possible to measure the savings of this particular project because it is incorporated into a program involving other building modifications.

Lehigh University installed outdoor thermostatic control valves on the principal incoming steam line of each of its nine academic buildings, all of which were built in the early 1900s. With the installation, any temperature above 50° F. will close a valve to keep the building from overheating. Cost of implementation was *$8,500*, with annual savings of *$8,500*.

Marquette University installed high- and low-limit thermostats on a heating and ventilation system that had been running continuously, twenty-four hours a day. The installation reduced the system running time by 90 percent, at a cost of *$40*, with annual savings of *$840*.

Princeton University installed individual-control, thermostatic valves on each radiator in its faculty apartments complex at a cost of *$4,000*, with estimated annual savings of *$900*.

Syracuse University modified the steam radiator system of a fifty-year-old classroom and office building, comprising 63,000 gross square feet, by introducing 300 individual temperature control valves. Cost to implement was *$26,147* with an estimated payback of 1.5 years.

Western Michigan University installed non-electric thermostatic heating control valves in each room of a 34-year-old building, comprising 200,730 gross square feet, that had been constructed with steam convector heat. Cost of implementation was *$14,078* with fuel savings of *$7,173* annually.

Modification of Chilled and Hot Water Systems

McMaster University connected all university buildings to a chilled water distribution network by altering pipe connections at the interface between the building chilled water system and the chilled water distribution network. These changes insure that chilled water temperatures rise to the prescribed delta T before the control valve introduces more chilled water to a building circulation system. Cost to implement was *$135,063,* with annual savings estimated at *$23,315.*

St. Louis Community College at Florissant Valley reduced the flow rate of the central plant ten-year-old chilled water system, which serves eleven buildings, by modifying two main chilled water pumps. This reduces the energy required to circulate chilled water by matching cooling loads with flow rate. Cost to implement was *$2,885* with annual savings of *$1,800.*

St. Louis Community College at Meramec modified (1) the hot water piping system to reduce the number of circulating pumps required for operation, (2) the chilled water system to convert the main system from constant flow to variable flow, and (3) the valving of the condenser water system to permit operation of only one cell of the cooling tower with each chiller. Cost of implementation was *$43,498* with annual savings of *$20,790.*

The University of Nevada at Las Vegas added piping to its two-year-old life sciences building (comprising 68,500 gross square feet) so that the cooling tower can be made to substitute for the 300-ton chiller. Dry climate allows the university to pump cooling tower water through the chilled water loop during cool periods so that the building can be cooled and the chiller turned off. Cost to implement was *$3,000* with annual savings of *$5,000.*

Boiler, Water Heater Changes

Princeton University replaced three 100-horse-power boilers, in a complex of 153 apartment units and 3 laundry rooms, with nine 20-horse-power boilers and a modified control system; all boilers are used on coldest days but only one may be needed during the nonheating season. Cost to implement was *$61,654,* with *$9,125* in annual savings. In addition, the university installed a heat exchanger in its chilled water plant to substitute for centrifugal chillers during winter months when cooling tower water temperatures were low enough to handle chilled water requirements. Cost to implement was *$65,000,* with annual savings estimated at *$17,000.*

St. Louis Community College at Florissant Valley added a heat exchanger to the central hot water heating system in order to operate a small steam boiler in summer for providing hot water for domestic and kitchen use, thus allowing three large main hot water generating boilers to be shut down. Cost to implement was *$13,300* with annual savings of *$2,900.*

St. Louis Community College at Forest Park modified kitchen equipment to allow for use of low pressure steam, thereby permitting the college to shut down its medium pressure boiler. Cost to implement was *$500,* with annual savings of *$1,000.*

Syracuse University installed small individual electric water heaters, thus permitting main steam lines to be turned off during the summer, with 35 percent reduction in steam consumption and 16 percent reduction in operating costs. Cost of implementation was *$21,000,* with annual savings of *$6,370* in steam and *$15,830* in electricity (the latter resulting from the shutdown of electrical equipment and appliances).

The University of Oklahoma is adding the Bailey Conserver Trim Combustion Control System to improve the firing efficiency of university boilers. A minimum 1 percent annual fuel saving is expected, or a one-year payback.

Make-up Air Control

Augustana College sets its outside air make-up controls down to a zero or minimum position in some buildings when they are unoccupied. No savings have been calculated as yet, due to recent implementation.

Kalamazoo Valley Community College has decreased the minimum air makeup on several units of its 1970 classroom facilities, comprising 242,372 gross square feet. Mixed air temperatures are increased where possible and chillers have been set to limit amperage draw. Cost to implement was *$200*, but no annual savings have been calculated as yet due to recent implementation.

McMaster University changed a dual duct HVAC system to VAV by changing mixing boxes to variable volume control and changing main fan motors to variable speed controlled by duct static pressure. Cost to implement was *$192,650*, with annual savings estimated at *$60,300*.

Occidental College retrofitted the air conditioning systems and installed controls to provide maximum use (up to 100 percent) of outside air for cooling in two facilities — a ten-year-old administration building comprising 37,943 gross square feet and an eight-year-old library comprising 101,834 square feet. Cost to implement was *$4,000* for the administration building, with estimated annual savings of *$15,000;* for the library, *$8,000* with estimated annual savings of *$20,000*.

The Ohio State University converted an outside air system to allow recirculation in in the winter and complete shutdown of air handlers in the summer during unoccupied hours; in addition, the university reduced the conditioned air exhausted from the building during occupancy to the minimum allowable by code. Cost to implement was *$23,575* with annual savings of *$19,315*.

St. Louis Community College at Florissant Valley initiated a project consisting of two parts: (1) adjusting and balancing the supply, return, and exhaust systems in all major building HVAC units to meet actual present building loads, and (2) modifying the fume hood exhaust system in a science and mathematics building. Cost of implementation is *$13,880*, with annual savings estimated at *$9,660*.

The University of Louisville has reduced fresh-air intake to a minimum wherever possible in all its buildings, and, in extremely cold weather, fresh-air intakes are covered with 6-millimeter polyethylene to prevent air leakage. It should be noted that animal quarters, chemical laboratories, and research and food preparation areas must be excluded from such a program. Cost to implement the project was approximately *$2,000;* annual savings are *$30,000*.

The University of Nevada at Las Vegas changed its heating, ventilation, and air conditioning duct system and controls so that the chilled air duct can be supplied modulated cool outside air and the chiller turned off. Duct temperatures are controlled by return air temperature. Cost to implement was *$4,000* with annual savings of *$8,000*.

Steam Traps

The College of St. Catherine overhauled or replaced all the steam traps in all campus buildings (comprising 1,021,866 gross square feet) at a cost of *$4,077*. Although it is not possible to estimate savings, the project was rated highly successful.

Southern Utah State College reconditioned all steam traps and cleaned strainers in 23 buildings ranging in age from 80 years to 1 year. A savings of about *$12,796* per year is expected.

The University of Wisconsin at Superior replaced all ½" x ¾" thermostatic steam traps having integral internal elements (most of which had failed) with Barnes & Jones single-piece "cage" units in three buildings: an eighteen-year-old physical education facility comprising 74,995 gross square feet, a sixty-year-old classroom and office building comprising 29,005 gross square feet, and a twenty-eight-year-old office building comprising 31,738 gross square feet. The change should reduce future maintenance costs, conserve steam, and permit periodic checking of elements for proper operation. Cost to implement was *$2,800*, with estimated annual savings of *$3,200*.

Miscellaneous

Central Michigan University insulated the heating pipes in a high-rise residence hall complex at a cost of *$15,000*, with annual savings of *$4,800*, a payback of 3.2 years.

Marquette University added a self-contained window heating/air conditioning unit to the telephone switchboard operation room of a seventy-year-old building, thus allowing shutdown of the main ventilation system when only the telephone switchboard is in use. Cost to implement was *$410*, with annual savings of *$10,000*.

The Massachusetts Institute of Technology reduced the speed of the supply fan in the main air conditioning system in its thirteen-year-old space science building (comprising 104,000 gross square feet) in accordance with

reduced air quantity actually required in the building. An 86 horsepower fan drive was reduced to 40 horsepower. Cost to implement was *$4,000* with annual savings of *$8,300*.

St. Louis Community College at Forest Park removed humidity controls in the cooling cycle in all its campus buildings, thus eliminating the use of heat to regulate the humidity in the summer cycle. Cost to implement was *$400*, with estimated annual savings of *$1,000*.

The University of Connecticut has had a moratorium on the installation of air conditioning for human comfort since about 1973, although it is in compliance with recent Connecticut codes, which establish air conditioning standards for public buildings. Variances from its 78°F. limit have been obtained for specific warranting conditions, primarily research laboratories. Annual savings are estimated at about *$75,000*.

The University of Louisville utilizes the heat from a utility tunnel, of which the main library basement is a continuation, to heat the library building. This is done by opening a door in the mixed air compartment, and drawing in heat from the tunnel; this also supplies the humidity needed for the library.

Building Operations

Central Controls, Time Clocks

The Algonquin College of Applied Arts and Technology installed a central monitoring and control system on two campuses (comprising about 500,000 gross square feet), including linkage between campuses, at a cost of *$300,000* with annual savings of *$60,000*.

Arkansas Technical University installed energy management controls on the HVAC system in six buildings at a cost of *$22,852* with annual savings of *$20,000*.

The College of William and Mary leased the services of an automated control system for the independent cooling systems in eleven buildings at a cost of *$62,000 for installation and $54,000 for the first years' lease*, with a net savings of *$18,000* the first year and expected annual savings thereafter of *$80,000*.

Dartmouth College installed a Honeywell 1000 Central Environmental Control System for fifteen major buildings, comprising about 1,100,000 gross square feet, at a cost off *$330,000*, with savings in less than a year reaching *$130,000*.

DePaul University installed a central mechanical automation system in its Lincoln Park campus at a cost of *$250,000*, with projected annual savings of *$80,000*.

The Juilliard School is installing an electromechanical system to automatically cycle the HVAC system in the school building (500,000 gross square feet) at a cost of approximately *$7,500* and estimated annual savings of *$24,000*.

Lehigh University installed a common slave time clock that manages a five-zone HVAC system on an individual program schedule for an eight-year-old building (comprising 57,800 gross square feet) at a cost of *$5,000* with annual savings of *$2,500*. In addition, the university installed a common slave clock managing three HVAC systems on an individual program schedule in a nine-year-old chemistry building comprising 22,840 square feet. Cost to implement was *$9,600* with annual savings of *$5,000*.

Marquette University reset time clocks controlling HVAC systems in most campus buildings to delay system startups by half an hour, which realized annual savings of *$3,500*. In addition, the university added individual time clocks to units of the HVAC in a twenty-one-year-old residence hall comprising 170,500 gross square feet, at a cost of *$380* and annual savings of *$5,200*. Further, the university installed a time clock to control the return and exhaust fans, and a time delay relay to delay startup of the supply fan in the HVAC of a five-year-old physics building comprising 76,500 gross square feet. Cost to implement was *$130;* annual savings, *$1,000*.

The Massachusetts Institute of Technology installed a central computer system for controlling HVAC systems in thirty-four buildings as well as for monitoring the performance of the central power plant. Cost to implement was *$2,000,000* with annual savings estimated at *$1,181,000*. In addition, the Institute installed an electric hot water heater with a time clock for use in summer in a thirty-year-old office and classroom building comprising 79,000 gross square feet. The hot water heater allows the main steam supply to be shut down during the summer, and the time clock permits avoidance of operation during peak electric consumption hours, as well as night shutdown. Cost to implement was *$400*, with annual savings of *$250*. The Institute also installed an HVAC system time clock control in entire buildings and in individual rooms, using both seven-day and twenty-four-hour time clocks, at a cost of *$300* to *$500*, depending on the size of the particular system.

Occidental College installed time clocks on the HVAC of several buildings; units are secured after working hours and on weekends. Cost to implement was *$3,000* with estimated annual savings of *$40,000*.

Princeton University installed 247 spring-actuated 12-hour timers with manual resets on all window air conditioners; units can no longer be left to run automatically night and day. Cost to implement was *$9,724*, with estimated savings of *$3,409*. In addition, the university installed a central supervisory control system to monitor and control HVAC equipment in nineteen buildings, ranging in age from 10 to 222 years — a total of 1,478,537 gross square feet. Cost to implement was *$2,147,000*, with annual savings estimated at *$300,000* by 1980.

Southern Illinois University at Carbondale introduced an IBM System 7 load shedding system, in 1974, at an implementation cost of approximately *$46,000* and annual savings (from the System 7 only) ranging from *$50,000* to *$70,000*.

Spring Arbor College added a time clock to control use of the air conditioning part of an HVAC system in its eighteen-year-old stu-

dent center, which comprises 20,000 gross square feet, thus reducing use of air conditioning during cool spring and fall weather. Cost to implement was *$153,* with estimated annual savings of *$600.*

Susquehanna University installed a Honeywell Delta 1000 Energy Management System in three buildings comprising about 177,400 gross square feet, at a cost of *$52,000* with annual savings of *$20,796.*

Syracuse University modified a five-year-old, all-electric building comprising 58,520 gross square feet using time clocks and temperature setbacks for nights and weekends. In twelve months, 1,400,000 KWH were saved in consumption. Cost to implement was *$2,000* and annual savings were *$37,000.* In addition, the university installed a Powers S170 Energy Management System which provides duty cycling, load shedding, on/off scheduling and alarm scanning for an all-electric, dual-duct, constant-volume system in its five-year-old library (comprising 340,290 gross square feet). Demand was reduced from 2,394 KW to 1,974 KW in one year. Cost to implement was *$90,000,* with annual savings estimated at *$75,000* to *$85,000.*

The University of Hartford installed an IBM System Seven to program the HVAC in all buildings, an area of 1,275,000 gross square feet. The equipment was leased, with an option to buy (purchase price is about $15,000) and approximately 5½ million KWH and about 75 thousand gallons of No. 4 fuel oil are saved annually.

The University of Louisville installed a central monitoring and control system in eight buildings and a central steam and chilled water plant, comprising 680,000 gross square feet. Cost to implement was *$200,000* with annual savings estimated at *$40,000* to *$45,000.*

The University of North Carolina at Chapel Hill installed seven-day programmable time clocks on the air distribution systems in thirty-one buildings at a cost of *$12,000* with annual savings of *$400,000.*

The University of Oklahoma used its own engineers and shop personnel to design, develop, and install a building central metering and HVAC control system for thirty buildings, comprising approximately 2,569,516 gross square feet. Cost to implement was approximately *$390,000;* since buildings were not metered previously, annual savings could not be calculated.

Steam Controls and Time Clocks

Augustana College installed a steam pressure reducing valve and two zone control valves, controlled from indoor temperatures, in a fifty-year-old residence hall comprising 42,227 gross square feet, at a cost of *$4,924* with estimated annual savings of *$1,145.*

Connecticut College installed "Heat-Timers" in fifteen academic and residence facilities heated by steam radiators, at a cost of *$19,500* and with estimated annual savings of *$5,000.*

Georgia Institute of Technology installed time clocks on campus steam lines; steam valves were cycled so as to provide temperatures of 65°F. during the day and 55° to 60°F. at night. Cost to implement was *$1,000,* with annual savings of *$35,000.*

Lehigh University installed a time clock with occupied/nonoccupied control in its ninety-year-old chapel (comprising 29,469 gross square feet) at a cost of *$2,980,* with a payback period of six months.

Marquette University reduced length of occupancy as programmed on the time clock on the single zone thermostat in a fifty-year-old classroom building comprising 18,600 gross square feet, with annual savings of *$1,400.*

The Massachusetts Institute of Technology installed steam radiation automatic controls in several buildings at a cost of *$1,000,* with annual savings of *$5,000.*

The University of North Carolina at Chapel Hill installed an electronic startup control on the main steam supply serving ten multizone systems in an eighteen-year-old classroom and office building comprising 63,690 gross square feet. Cost to implement was *$1,200* with annual savings of *$6,000.*

Operating Schedules

Cleveland State University designed a weekly fan schedule from the class and activity schedule of its six-year-old physical education building, which comprises 201,216 gross square feet. Cost to implement was *$1,530* with annual savings of *$73,768.* Other buildings for which this was done are a nine-year-old classroom facility comprising 350,600 gross square feet, with annual savings of *$47,977;* an office building and student center comprising 198,219 gross square feet, with annual savings of *$19,991;* and a library and

office building comprising 481,557 gross square feet, with annual savings of *$134,042.* Implementation costs for all buildings were the same.

Kalamazoo Valley Community College shuts down approximately 700 horsepower of air handlers, chillers, etc., in its classroom building, when facility is unoccupied. Cost to implement was *$1,000,* with annual savings of *$50,000.*

Miscellaneous

Purdue University-North Central Campus changed operating times and methods involving electrical consumption, installed time clocks, and changed lighting levels in an eleven-year-old classroom building comprising 108,314 gross square feet and in a three-year-old, all-purpose building comprising 99,023 gross square feet. Implementation cost was *$5,000* with annual savings of *$51,000.*

The University of Connecticut has worked out a fuel contract method in which vendors bid on a specification based on heating value rather than volume only, and as a result has realized about *$12,000* in savings annually.

Utilities Production, Distribution

Chilled Water, Cooling Tower Alterations

The Georgia Institute of Technology cross-piped two 2000-ton chillers, allowing both chilled water pumps to feed either chiller, increasing flow and raising chilled water delivery temperature. Cost to implement was *$10,000* with annual savings of *$5,000*. In addition, the Institute provided independent cooling capability for specialized computer center equipment at a cost of *$80,000*, increasing chiller efficiency and saving about *$30,000* annually.

Pepperdine University installed an HVAC system using uniquely designed water heat pumps, coupled with underground hot water storage and using reclaimed sewage water in the cooling tower, in its new law school facility, which comprises approximately 88,500 gross square feet. Savings in energy are estimated at 50 percent of the costs of a conventional system.

Princeton University installed thirteen secondary chilled water pumps in eleven buildings, providing better use of the chilled water produced and delivered by the central chilled water plant and reducing energy for pumping horsepower. Cost to implement was *$392,080* with estimated annual savings of *$36,708*. In addition, the university installed a valved cross connection between two cooling tower basins, permitting flexibility in selection for operation of any combination of five condenser water pumps and five cooling tower cells. Cost to implement was *$14,745* with annual savings of *$9,000*.

The University of Oklahoma installed cooling tower drift eliminators, improving the efficiency of a three-cell tower by 15 percent and the efficiency of a two-cell tower by 40 percent, resulting in annual savings of *$5,241.60* (payback of about three years) and *$14,970.00* (payback of about one year), respectively.

Steam Conservation, Condensate Return

Drexel University instituted a method of steam conservation to reduce steam demand and installed a heat recovery system to assist in heating the swimming pool. Cost to implement was *$28,508*, with anticipated savings of *$16,930* annually.

Eastern Michigan University trained operators to provide better chemical treatment in feedwater and condensate, resulting in annual savings of *$2,371*.

Lehigh University insulated steam lines and condensate return lines in a steam tunnel of 1,075 linear feet at a cost of *$19,000*, with annual savings of *$5,000*.

The University of Iowa has begun insulating condensate return lines from campus buildings to the central heating plant at a cost thus far of *$93,673* and annual savings of *$28,530* on the portion completed.

The University of North Dakota replaced leaking condensate return mains with direct burial fiberglass piping, increasing the amount of condensate returned to the central plant from 55 percent to 88 or 90 percent. This results in triple savings: less makeup water, fewer chemicals needed for treatment of makeup water, and the fuel that was formerly needed to heat makeup water to the condensate temperature. Cost to implement was *$163,252*, with annual savings of *$30,000*.

Miscellaneous

Augustana College replaced a worn-out hot water heater in a thirteen-year-old residence hall with a shell and tube heat exchanger connected to the main boiler; a storage tank was installed and shower heads changed from 5 gpm usage to 2 gpm. Cost to implement was *$13,031*, with annual savings of *$1,700*.

St. Louis Community College at Florissant Valley modified the central hot water piping distribution system to permit a reduction in flow rate from 1,260 gpm to 600 gpm and a reduction in the primary system head of twelve feet. Engineering costs for the project were *$750* and construction costs were *$8,800*. Annual savings of *$4,860* are expected, or a payback period of two years.

The University of Michigan installed new turbine generators, enabling the university to generate about three times as much electricity as it did prior to installation. Cost to implement was about *$54,000*, with estimated savings of *$36,000* annually, or a payback of one and one-half years.

Student, Faculty, and Staff Programs

Awareness Programs

Syracuse University converted laundry facilities (200 washers) from hot and cold water to cold water only, with instructions posted for washing with cold water. Cost to implement was *$1,500* with estimated annual savings of *$35,000.*

The University of Louisville implemented a public awareness program to conserve energy in the use of elevators and lighting, at a cost of *$200;* savings cannot yet be calculated.

The University of North Carolina at Chapel Hill established an energy conservation awareness program by inserting flyers in the *Daily Tarheel,* the institution's newspaper; placing energy reminders on fume hoods; placing energy reminders on light switches; and issuing door-hanger notices to the housekeeping department for placement when a violation of conservation practices occurs.

Energy Conservation Advisory Committee

The University of Pittsburgh established a university-wide energy conservation advisory committee which is concerned with practical and measurable energy conservation projects involving utility systems, building and plant operations, and university programs and activities that significantly affect energy use. The ultimate objective is to reduce university energy use by 30 percent over a three-year period.

Four-day Week; Longer Breaks

Delaware County Community College adopted a four-day week, offering two six-week semesters in addition to two traditional fifteen-week semesters on a Monday-through-Thursday basis; administrators and staff work four ten-hour days. This shortened work week, plus the elimination of weekend activities, has enabled the college to operate the same equipment at about half the cost, realizing annual savings of *$47,000.*

Morton College eliminated day school during the summer semester, holding classes between 6 p.m. and 10 p.m., thus reducing air conditioning demand by about 75 percent. The work schedule for the administrative staff was changed to a ten-hour day and a four-day work week.

The University of Connecticut implemented a total "Christmas shutdown," closing the university from December 23 to January 16. Cost to implement is *$3,000* annually, with annual savings of *$25,000.*

Showerhead Replacement

The following institutions replaced showerheads or installed water-flow restrictors:

Institution	*Cost*	*Annual Savings*
Southwestern University at Memphis	$ 860	$ 4,400
College of St. Catherine	1,660	830 (estimated)
Syracuse University	30,000	150,000
Occidental College	300	2,000 (estimated)

Miscellaneous

Southwestern at Memphis student government bought smaller, more energy-efficient refrigerators to replace older, high-energy-consuming refrigerators then in use by students. The new refrigerators were rented to the students and approximately *$300* was realized in savings.

The University of Connecticut established a program whereby two energy monitors are assigned to each academic building, with the responsibility of investigating all heat complaints in the building and reporting to physical plant personnel. Cost to implement this program was about *$2,000;* it is not possible to determine savings.

The University of Iowa established a campus-wide policy on air conditioning for personal comfort from April 15 to October 15; previously, the air conditioning systems had been operated on departmental demand.

Index of Institutions

Index of Institutions

Following is a list of institutions whose energy management projects appear in this publication, with persons or offices to be contacted for further information:

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